STARS

Affordances In The Design Of Virtual Environments

David Charles Gross
University of Central Florida

STARS Citation

AFFORDANCES IN THE DESIGN OF VIRTUAL ENVIRONMENTS

by

DAVID CHARLES GROSS

B.S.C.S. Auburn University, 1985
M.S.O.R. University of Alabama at Huntsville, 1992

A dissertation submitted in partial fulfillment of the requirements
for the degree of Doctor of Philosophy
in the Department of Industrial Engineering and Management Systems
in the College of Engineering and Computer Science
at the University of Central Florida
Orlando, Florida

Spring Term
2004

Major Professor: Dr. Kay M. Stanney, Ph.D.

ABSTRACT

Human-computer interaction design principles largely focus on static representations and have yet to fully incorporate theories of perception appropriate for the dynamic multimodal interactions inherent to virtual environment (VE) interaction. Theories of direct perception, in particular affordance theory, may prove particularly relevant to enhancing VE interaction design. The present research constructs a conceptual model of how affordances are realized in the natural world and how lack of sensory stimuli may lead to realization failures in virtual environments. Implications of the model were empirically investigated by examining three affordances: passability, catchability, and flyability. The experimental design involved four factors for each of the three affordances and was implemented as a 2_{IV}^{4-1} fractional factorial design. The results demonstrated that providing affording cues led to behavior closely in-line with real-world behavior. More specifically, when given affording cues participants tended to rotate their virtual bodies when entering narrow passageways, accurately judge balls as catchable, and fly when conditions warranted it. The results support the conceptual model and demonstrate 1) that substituting designed cues via sensory stimuli in available sensory modalities for absent or impoverished modalities may enable the perception of affordances in VEs; 2) that sensory stimuli substitutions provide potential approaches for enabling the perception of affordances in a VE which in the real world are cross-modal; and 3) that affordances relating to specific action capabilities may be enabled by designed sensory stimuli. This research lays an empirical foundation for a science of VE design based on choosing and implementing design properties so as to evoke targeted user behavior.

ACKNOWLEDGMENTS

I acknowledge and express my deep appreciation for the members of my committee for their guidance and assistance in overcoming the many technical issues raised in this research.

I acknowledge and appreciate the free exchange of ideas, criticisms, and suggestions with my colleagues in the technical community. In particular I recognize Lt. Joseph Cohn, Ph.D. for his review of the early conceptual work, and Mr. Lynn D. Stuckey, Jr. for serving as a sounding board countless times.

I acknowledge and appreciate my employer, the Boeing Company, for permitting me the opportunity to carry on this research. In particular, I recognize my supervisor, Mr. William V. Tucker, for his support and encouragement.

I extend my warmest gratitude to Dr. Kay M. Stanney, the chair of my committee, for her patience and commitment to leading me through this long process, for the many technical interchanges we have had on this topic over the years, for her contribution to my technical education, and perhaps most of all for her enthusiastic response to my answer on a final exam which lead to this research.

I dedicate this work to my wife, Sheryl Anderson Gross. This effort has cost her more than it has me.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1: INTRODUCTION

The potential of virtual environment (VE) technology has captured the imagination of the scientific community as well as the public at large. VE technology is exciting, both because it offers a unique approach to effective human computer interaction (HCI) design, and because it may support computer assisted task performance in new or unprecedented ways (Pejtersen & Rasmussen, 1997). Engineering communities presume that VEs offer dramatic advances in the ability to design HCIs in entertainment, education, training, and other computer assisted applications (Stuart, 1996). For example, VEs may provide a new tool for gaining understanding from information (Pejtersen & Rasmussen, 1997). VEs also figure prominently in popular television series. Popular science fiction assumes the routine creation and use of synthetic three-dimensional worlds as believable as the real physical universe (Vince, 1995).

VE interface designs are unique because they aim to represent a virtual world, in which users may experience a strong sensation that they are present in, or part of, a computer generated world. Since humans are experienced with operating in the real world, VEs may offer a more natural interface than more conventional HCI (Norman, 1993; Shneiderman, 1998). For example, one common HCI challenge is designing effective interfaces *to* databases but within the virtual world, it is possible to place observers at any point *in* a database, allowing them to adopt any convenient perspective (Anders, 1999). Although the VE represents a world, it is not necessarily bound by the conventions of the real world (e.g., it need not conform to the laws of Physics). For example, humans can be endowed with the ability to "fly" over a virtual map, which could simplify learning geography and applying that knowledge in planning navigation routes. Thus, ideas that are difficult

to convey via conventional means may be more readily "experienced" in a virtual world. One of the most useful benefits of VE technology may be this ability to use unique data representation schemes to gain understandings and insights (Norman, 1993; Sheridan, 1992).

The representation of a virtual world in a VE may provide several important benefits for task performance, including: expanding human memory, enabling group collaboration, and supporting transmission of ideas across time and space (Norman, 1993). Conventional HCI design proceeds from the assumption that the tasks to be done are stable and strongly structured. Such systems tend to well support work focused on producing a specific product, such as a document, or making a calculation. In contrast, VE designs may proceed from the expectation that the tasks to be performed in them will be dynamic and free flowing, because they aim at representing a world with the complex interactions typified by real experience (Anders, 1999). Therefore, VEs should better support more dynamic, or loosely structured, tasks such as exploration or military training (Pejtersen & Rasmussen, 1997).

Despite their potential, current VEs have proved less usable than expected or desired (Stuart, 1996). Lombard and Ditton (1997) note that there is limited research as to whether these new interface technologies are more effective or efficient than conventional HCI technologies. For example, Pausch, Shackelford, and Proffitt (1993) demonstrated that greater immersion in a VE can increase task efficiency, but assert that more research is needed to identify the characteristics of tasks for which the VE enhances performance. Anders (1999) notes that VEs have been shown to be effective in communicating dimensional or geometric information to users, but less effective in enabling VE users to determine their behavioral reactions within those spaces.

Since VEs are implemented as computer interface devices closely fit to humans, improving VE design has both ergonomics and human factors challenges. The challenge for ergonomics is the

design of VE components such as data gloves and visual display helmets (Kalawsky, 1993). The challenge for human factors is the design of the virtual world representation. Although the ergonomics challenges are significant, since a virtual world representation is realized primarily in the mind of users, the human factors issues may be more challenging (Vicente, 1999). Stanney, Mourant, and Kennedy (1998) classify the potentially unresolved human factors issues for the design of VEs as: 1) human performance issues, 2) health and safety, and 3) social implications.

There are unique human performance issues in VEs, as compared to conventional HCI, because the human performs differently in immersive (e.g., helmet-mounted display-based) environments than in non-immersive environments. One specific example is human perception in VEs, as the National Research Council's recent survey on VE recognizes by calling for research "on how well the design accounts for human perceptual and cognitive features for human responses" (Durlach & Mavor, 1995, p. 65). In a specific example, Dixon, Wraga, Proffitt, and Williams (2000) have shown that, just as in the real world, observers use their perceived eye-height to judge the size of objects presented in an immersive virtual environment. This is not true in non-immersive (conventional) displays, but appears to be spontaneously evoked in immersive environments.

Perception is at the core of human performance issues because it is fundamental to cognitive processing (Wallach, 1976; Warren & Wertheim, 1990). Existing HCI design principles assume perception is essentially a response to a sensory stimulus, and focus primarily on visual stimuli to the neglect of other sensory modalities (Card, Moran, & Newell, 1983). However, perception is more than just stimulus and response, including for example attention, motivation, and stimulus integration (Rensink, O'Regan, & Clark, 1997). Stimulus integration is the process of combining sensory stimulation in different modalities into a consistent understanding of the world. Human perception is always multimodal; therefore HCIs which seek to provide an immersive experience may need to account for multimodal stimuli if their users are to correctly perceive the information

3

presented to them (Popescu, Burdea, & Trefftz, 2002; Sharma, Pavlovic, & Huang, 1998; Shimojo & Shams, 2001). If a user cannot perceive what a VE enables, then the experience may be frustrating and non-productive, decreasing the usability of the virtual environment.

A core human performance issue therefore in VEs is designing the virtual world representation in such a way as to enable user's perception, i.e., to understand what can and should be done in the virtual environment. HCI design principles do not, however, appear to adequately address perception. This suggests that a productive area of research is the extension and application of psychological theories addressing perception to the design of VEs (Barnard & May, 1999; Pratt, Zyda, & Kelleher, 1995). The question for VE designers is inverted, however, from questions addressed by traditional psychological theories. Instead of understanding how humans perceive what naturally occurs in the real world, VE designers need to understand how their designs support and exploit natural perception within the virtual world they represent. More specifically, the issue for VE design is how the user perceives the objects, properties, and behaviors selected by the VE designer for inclusion in the virtual world. This is a direct result of the fact that the only way for developers to communicate with users is through the artifacts of their design evidenced in the interface (Anders, 1999).

One compelling way of thinking about human perception is the theory of direct perception, which says that humans can (and do) directly perceive the possible actions in an environment or conversely what the environment affords to the human (Gordon, 1989). The issue is whether or not VEs can be designed to provide the same level of direct perception.

The theory of direct perception revolves around two concepts: affordances and invariants. Affordances are the inherent uses that an object in the world furnishes to their user, for good or ill. Invariants are higher-order properties or patterns of stimulation, which remain constant during

4

changes associated with the observer, the environment or both. Affordances are therefore a form of communication between objects and their users, and invariants a model of how they are used (Gordon, 1989). Affordance theory explains the interaction of an organism with its environment, under the premise that perception is an important cognitive process (Gibson, 1979).

The present research investigates the resulting implication that VE interface designs which are sensitive to the match between their actual affordances and their intended functions should be more usable than affordance insensitive designs. The present research first constructs a conceptual model of how affordances are realized in reality and how sensory stimuli missing in a VE prevent the realization of affordances in virtual environments. Second, the research aims to demonstrate that VE designs can enable the realization of affordances by overloading of absent sensory stimuli modes onto sensory modes extent in the interface. Finally, the research aims to demonstrate that VE designs that enable affordances are more usable, in terms of ease and efficiency of user movement, than VE designs that do not.

CHAPTER 2: BACKGROUND

Perception and Multimodal Sensory Stimulation

Humans, like all animals, experience their natural environment through continual multimodal sensory stimulation, and this multimodal stimulation is fundamental to correct perception. In a famous experiment, Lee and Reddish (1981) while observing the behavior of gannets (a bird that feeds by diving on fish in water), determined that the bird's decision on when to fold its wings for entry into the water was a function of the stimulation available to the bird in the visual and kinesthetic sensory modalities. In a fundamental finding for human perception, Gibson and Mowrer (1938) showed that the perception of uprightness is complex, dependent on integration of visual and kinesthetic (e.g., the effect of gravity on posture) information. Gravitational factors were shown to be preeminent to visual factors in the determination of the perceived vertical, although distorting visual information led to a distorted perception of the vertical. Similarly, Cutting, Wang, Fluckiger, and Baumberger (1999) provide a summary of literature arguing that pedestrians integrate visual stimuli with kinesthetic and vestibular information in order to make heading judgments. Kolev, Mergner, Kimmig, and Becker (1996) showed that perception of object motion in space in the absence of a visual background depends strongly on vestibular and visuo-oculomotor cues.

The fact that humans experience the natural world through continual multimodal sensory stimulation has significant implications for the present research. If VEs seek to provide immersive experiences, e.g., experiences where the user feels a strong sense of being part of the virtual world, then it is likely that such HCIs will have to address the user's natural expectation of multimodal sensory stimulation. Sharma et al. (1998) suggest biological, mathematical, and practical reasons for

6

using multimodal human computer interfaces. Biologically, sensory signals from all sources converge to the same target area in the superior colliculus, which also receives signals from the cerebral cortex, which in turn regulates behavior. The majority (~75%) of neurons leaving the superior colliculus carry multisensory information. This implies that not only do humans experience the world through continual multimodal sensory stimulation; their brains are "wired" to accept such stimulation, which increases the likelihood that single or limited mode stimulation will not always lead to correct perception. The mathematical motivation for using multimodal HCIs is that statistical data analysis suggests that increased accuracy results from combining multiple sensory sources. Just as multiple samples can improve the accuracy of an estimated population parameter, multiple observations in different modalities of the same source can be combined to increase the accuracy of the understanding of the source. Finally, the practical reasons they cite include increased naturalness, robustness, and accuracy, all of which VE systems aspire to achieve.

Ordinary understanding names five sensory modalities (sight, hearing, touch, taste, and smell) by which humans perceive their environment. However, this understates the complexity of the human sensory system. Table 1 shows specific human sensory modalities by category, and the kinds of information they transduce (Forgus & Melamed, 1976). Transduction is the process by which sensory systems translate physical information available in an environment into information messages on which the nervous systems acts. All sensory systems transduce four kinds of information: 1) sensory modality and sub-modality, 2) stimulus intensity, 3) stimulus duration, and 4) stimulus location (Forgus & Melamed, 1976). Exterocepters are sense organs that are adapted for transducing energy from external stimuli (i.e., those outside of the body, such as light and sound). Proprioceptors are sense organs that respond to direct contact with external stimuli (e.g., taste, smell, pressure). Interceptors are sense organs that respond to internal stimuli within the body itself (e.g., body motion, balance, thirst).

Table 1: Human senses and information transduced (Forgus & Melamed, 1976).

Class	Sense	Energy Transduced
Exterocepters (distance)	Vision	Light
	Audition	Sound
Propriocepters (near)	Cutaneous (skin)	Pressure, temperature
	Gustation (taste)	Chemical (liquids)
	Olfaction (smell)	Chemical (gases)
Interceptors (deep/internal)	Kinesthetic (dynamic)	Body motion
	Vestibular (static)	Body balance, rotation, acceleration
	Organic	Organ function, such as thirst, hunger

The variety of sensory modalities and energies transduced by the human senses has at least two implications for VE interface designs. First, such designs may need to account for all modalities if they are to create a truly immersive experience. There are three alternatives for accounting for the modalities: 1) correlate sensory stimuli to the experience represented in the virtual world, 2) determine a particular modality is irrelevant to the experience, or 3) substitute information in another modality for missing modalities. Second, VE interface designs face a difficult challenge if they seek to present sufficient stimuli to enable a truly comprehensive correlation of all possible sensory modalities, because of the complexity of the modes and stimuli.

It is possible to construct a model of a human interacting with its environment via these various sensory modalities. Figure 1 illustrates such a model, showing multimodal sensory stimulation as integral to correct perception in humans. Within this model there are two classes of sensory modalities: external and internal. Changes in the internal organs produce internal stimuli, whereas changes in the external environment produce external stimuli. Occasionally, perception begins with changes in internal stimuli, e.g., changes in the organic sense might lead to the perception of hunger. Typically however, perception begins with external stimuli arising from objects in the environment, which transmit or reflect energy to an organism. These external stimuli

arise as energy from objects in the environment forms a distal stimulus, which is energy reflected or

transmitted as measured at the object. When the stimulus energy reaches a sensory receptor (e.g.,

the eye), it becomes a proximal stimulus. There is an energy loss between the distal and proximal

stimuli, which is due to environmental effects such as water vapor and air pressure. As the

peripheral components (i.e., sensory receptors) are stimulated, they emit mediated stimuli which are

nerve impulses moving to the central nervous system from the peripheral nervous system (a process

called affection). The perception process is complete when the organism forms a "precept" (that

which is perceived), and which in humans is generally multimodal (Reber, 1995). This precept forms

a basis for other cognitive activities, which lead to decisions to select and exercise environmental

effectors, such as the arm or leg.
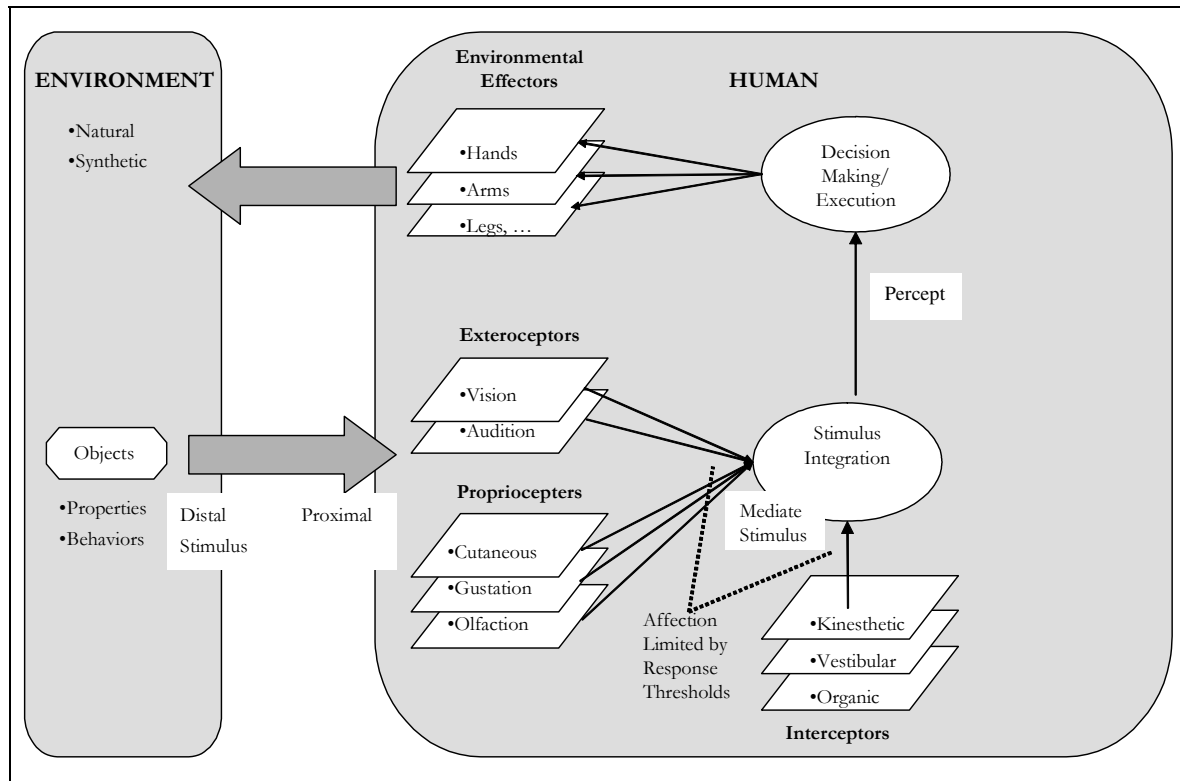
Figure 1: Multimodal sensory stimulation integral to correct perception.

The use of precepts results in decisions by the human that affect the environment, which in turn leads to new environmental stimuli. It is through such decisions and resulting actions that the human has influence on the environment, either changing the environment itself or one's position in it. The human's observation of the stimuli-decision-action cycle becomes a feedback cycle that also affects perception (Norman, 1988). As such, the specific environmental effectors available and the individual's experience with them, have influence on the precepts formed. For example, the human perceives a surface is suitable for walking both because of the stimuli the surface presents to the senses, and because the human has legs capable of walking. The human does not perceive whether a space is suitable for flying, until equipped with a capability for flying. Such additional capabilities may be real (e.g., the human is flying a plane) or potential (e.g., the human is considering flying a plane) or fanciful (e.g., the human is given wings). The human's knowledge of and experience with environmental effectors leads to an understanding of the available action capabilities using those effectors, such as walk, crawl, run, etc. In a like fashion, additional internal state information such as current goals, motivations, and knowledge of stature (e.g., size, reach …) influence perception (Marik, 1987; Norman, 1988; Rensink et al., 1997). For a percept to be formed, such internal state information and environmental multimodal sensory stimuli must have a certain intensity and duration to be perceived.

Environmental and internal state stimuli exist continually, however; the human sensory system is primarily designed to capture significant *changes* in such stimuli. As aforementioned, all sensory systems transduce information on stimulus intensity and duration. Some stimuli are of insufficient intensity or duration to activate a response in a particular sensory modality, and therefore fall below the response threshold for the sensory receptor involved. The minimum thresholds vary for each

sensory modality, and indeed for different sensory receptors within a modality, e.g., rod and cone cells in vision. Stimuli failing to rise above this minimum threshold do not lead to new percepts. Further, different individuals respond with different sensitivity to stimuli. It is, however, possible to construct a response function curve that approximates the response threshold for a population (Grandjean, 1988). There are many techniques for determining a response function. Figure 2 illustrates a typical psychophysical response function (Proctor & Proctor, 1997). The response threshold is the stimuli intensity that is detected 50% of the time (an arbitrary threshold). The S-shape of this curve results from the typically normal distribution of the population being sampled.
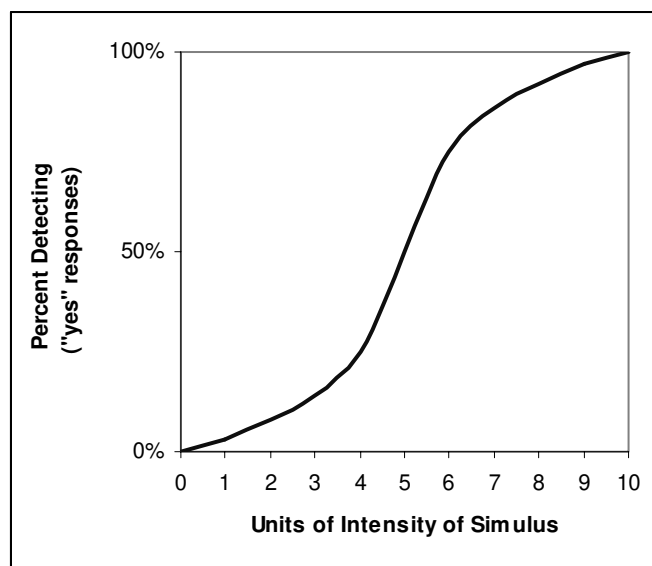
Figure 2: Typical S-shaped psychophysical function.

VE designers can exploit these minimum response thresholds. Watson, Walker, Hodges and Reddy (1997), for example, applied knowledge about the capabilities of the human visual system to the problem of reducing demands on visual scene rendering. Seeking to reduce computational

demands associated with rendering a visual scene for a VE, they found that they could exploit the non-uniformity of human vision by managing the level of detail of visual information at the periphery. By degrading the quality of the rendered scene only at the periphery, they succeeded in lowering computational requirements while not affecting task performance. That there are minimal response thresholds for each sensory modality has significant implications for VE system design. If a designer wants users to perceive a stimulus, it must exceed the minimal threshold, and if the designer is seeking to avoid users perceiving a stimulus (e.g., lag), it must fall below the threshold.

Substantial research has been conducted into the response thresholds specifically of exterocepters (visual and auditory senses) and toward exploiting this information in HCI (see Cain & Algom, 1997; Forgus & Melamed, 1976; Grandjean, 1988; Proctor & Proctor, 1997; Regan, 2000; Wallach, 1976). The visual and auditory senses are accessible in the sense that video and multi-channel sound systems provide a reliable means of providing stimuli to the visual and auditory senses. VE designs can present visual and audio stimuli, which completely replace stimuli from the natural environment, although such stimuli may not have a sufficient degree of fidelity to make the observer believe it is real. As a result, VE designers can develop and correlate such synthetic visual and audio stimuli with the virtual experience desired.

In contrast with exterocepters, the response thresholds of propriocepters are only generally known (e.g., sensory attributes of the skin are still difficult to quantify and exploit) and those of interceptors are even less well known (Proctor & Proctor, 1997). Further, there exists no reliable and economical way of providing propriocepters and interceptors with artificial stimuli (Barfield & Furness, 1995; Vince, 1995; Stuart, 1996). As such, propriocepters and interceptors are inaccessible as compared with exterocepters. Further, while propriocepters and interceptors may play an important role in perception particularly in awareness of self, VE designers have little understanding and inadequate means for creating artificial stimulation for these senses, or for correlating such with

the desired virtual experience. As a result, if VE users experience propriocepters and interceptors stimuli they will likely be from their natural environment (e.g., weight of the Head Mounted Display [HMD], or pressure of the chair they sit in during immersion) and may be in conflict with the synthetic world within which they are immersed. In contrast, exterocepters can be stimulated with information correlated to the desired virtual experience.

This inability to provide stimuli to propriocepters and interceptors is a problem because some of the percepts that VE designers desire to enable may depend on the integration of multimodal sensory stimulation including propriocepters and interceptors. Thus, substitution schemes for the inaccessible stimulation of propriocepters and interceptors may need to be pursued to enable correct perception. More specifically, designers could determine if it is possible to use available exterocepters, such as visual and auditory stimuli, to provide perceptual cues for requisite but absent propriocepter and interceptor stimuli. Such schemes would not replace the continual natural stimulation of propriocepters and interceptors. Nor would it change the affection of nerve signals resulting from this natural stimulation, since there are at present no direct neural inputs that can substitute for the propriocepters/ interceptors to central nervous system connection. The objective of such substitution schemes would be to enable correct perception by providing stimulation via exterocepters, outweighing the ongoing natural stimulation of propriocepters and interceptors (e.g., from the HMD, chair, etc.), or substitute artificial stimulation for propriocepters and interceptors correlated to the virtual environment. When natural stimulation falls below the response threshold of a sensory modality (such as occurs in the kinesthetic sense when not moving a limb), substitute stimulation would simply have to exceed the response threshold. When natural stimulation exceeds the response threshold, substitute stimulation would have to exceed the natural stimulation by a sufficient amount related to the response threshold to force response to the substitute rather than the natural.

Such schemes may succeed for two reasons. First, propriocepters and interceptors stimuli are relatively weak during typical human-VE interaction because of lack of user movement, as well as lack of other sensory modality stimulation (e.g., taste, smell). Unless there is a motion base involved, users generally do not have any intrinsic need to shift body posture to any great degree during VE exposure, except for invoking arm and hand motions, which relate to the virtual experience. While propriocepters and interceptors are continually stimulated, they detect best changing stimuli and eventually cease detection if continually exposed to the same stimuli (Forgus & Melamed, 1976; Proctor & Proctor, 1997). For example, a human who is not moving "forgets" the position of the body's limbs, although a very slight movement is all that is required to perceive the body's position. This implies that exterocepter sensory substitution schemes are more likely to succeed if stimulation of propriocepters and interceptors is minimized, perhaps by immobilizing the user.

Second, a substitution scheme may succeed because perception depends on integration of various sensory stimuli. Reber (1995) for example, defines perception as collectively, 1) the processes that give coherence and unity to sensory input; 2) awareness of a process; and 3) synthesis and fusion of elements of sensation. While the formation of mediate stimuli, that is, the conversion of the stimuli presented to the senses into nerve signals for transmission to the central nervous system, is understood to some extent, much less is understood about how these stimuli are integrated into a precept. The mechanics of sensory integration are not well understood, however, conclusions about the relative importance of various sensory modalities in the sensory integration process can be drawn from observations about the structure of the brain (Kadunce, Vaughan, Wallace, & Stein, 2001; Popescu et al., 2002; Sharma et al., 1998). Specifically, the brain devotes relatively large portions of its processing capacity to processing visual sensory stimulation, so it may be argued that visual information has relatively more weight in the sensory integration process (Proctor & Proctor, 1997). This leads to the phenomena of visual dominance, which refers to the

preeminent influence that visual stimuli have on perceptions. Stein and Meredith (1993) note that unless stimuli in a competing sensory modality are especially intense, visual stimuli provide the basic influence as to the interpretation of sensory stimulation One example of this is the ventriloquism effect in which the visual stimuli of a dummy's mouth leads to the perception that the dummy is actually speaking (Storms, 2002). This has important implications for a sensory substitution scheme, because it suggests that such a scheme may exploit the relatively greater weight of the visual sense in substituting for other senses.

The literature includes findings that support this design approach. Ijsselsteijn, Freeman, de Ridder, Avons, and Pearson (2000) measured posture responses to moving video, with various quality of display gear, and found that indeed posture changes were more noticeable when more immersive, higher resolution displays were used. Regenbrecht, Schubert, and Friedmann (1998) showed that visual displays such as those used in VEs can induce emotions, specifically the fear of heights. This is a strong indication of the ability of visual displays to evoke perceptions even when they are not correlated with other sensory stimuli normally associated with a given percept. For example, a moving picture can evoke the sensation of motion through visual stimuli, even though interceptors do not indicate motion.

The appropriate visual or auditory exterocepter stimuli to substitute for proprioceptors and interceptors that are not correlated to the desired virtual experience would naturally depend on the perception to be enabled. It is therefore essential to develop an understanding of how the role of the senses in perception may be transformed while immersed in a VE and how this will affect integration of perceived stimuli into a percept via the (likely different, possibly diminished) action capabilities that can be realized in a virtual environment. One model that ties the attributes of objects that stimulate sensory modalities to the actions that can be taken with those objects is the

theory of affordances. As aforementioned, affordance theory describes how humans directly perceive objects in their environment.

Affordances

The success of a sensory substitution scheme depends on an understanding of how the factors discussed: multimodal stimuli, available effectors, experience, attention, consistency, motivation, organization, attitude, and learning; are integrated into a percept. If this integration process is well understood, then designers can exploit that understanding in their design of sensory substitution schemes. The integration process required to form a percept is not at this time well understood (Rensink et al., 1997). Figure 1 illustrates this lack of understanding by representing the process of integration to form a percept as a "black box". Various models of this process can and have been constructed, which explain this integration to a greater or lesser extent (Wertheim, 1994). One powerful model of this process is presented by the theory of direct perception, in particular its concept of affordances. Affordances may be particularly relevant to the problem of designing a sensory substitution scheme because affordances draw heavily from an integrated perspective of animals acting in and directly perceiving their environment.

Definition

Direct perception, or ecological psychology, was first advanced by J.J. Gibson (Gibson, 1979). J.J. Gibson's theory of perception derives from his assertion that most of our knowledge of the world around us is not simply based on our experience, but on our expectations. Gibson's theory revolves around two concepts: affordances and invariants (Gordon, 1989). Affordances are the inherent uses that an object in the environment furnishes to their user, for good or ill. An object is said to afford a function to potential users. An object's complete set of affordances defines its possible functions. Affordances are therefore a form of communication between objects and their

users. Humans tend to use objects in ways suggested by the most conspicuously perceived

affordances, not in ways that are difficult to discover. Invariants are higher-order properties or

patterns of stimulation, which remain constant during changes associated with an observer, the

environment or both (Gordon, 1989). Affordances are neither objective properties, nor are they

purely perceptual (Kuhn, 1996). They capture how human beings understand what they can do with

their environment. Affordances offer clues to the environment's operation. Researchers in direct

perception have somewhat varying notions of just what an affordance is, although a general

consensus emerges in Table 2 by comparing definitions found in various works, and arranging them

in chronological order.

Table 2: Various definitions of affordances.

Researcher	Definition
Gibson (1979)	The inherent uses that entities furnish to their user, for good or ill
Warren (1984)	Functional utilities of an object for an animal with certain action capabilities; they exist whether or not they are perceived
Bingham and Muchisky (1992)	Dispositional or relational properties
Reber (1995)	The "invitational" quality of a percept for an event; intrinsic properties of items and events
Kuhn (1996)	Captures how a human understands what can be done in an environment
Oudejans, Michaels, Bakker, and Dolne (1996)	Active pickup of meaningful information that specifies the behavioral possibilities of an environment
St. Amant (1999)	Relationships or properties of relationships or Actions (actual, potential actions) or Perceived properties or Mental constructs
Lintern (2000)	Functional properties

A simple example will serve to illustrate. It is clearly seen that a chair affords *sitting* to humans. What is less clear is how a chair accomplishes this affordance while at the same time affording many other possible functions, for example: standing, climbing, blocking, and bashing. How is this possible? The goal "to sit" is invariantly associated with certain properties. What properties are sought in a place to sit (i.e., a seat)? Humans want seats that are flat, level, knee height, and so forth. There is an acceptability range for each property: The seat need not be perfectly flat, or exactly at knee height for example. The invariants associated with sitting explain how humans are able to instantly adapt to an incredible number of seats, including chairs never sat on and chair designs never before seen. In addition, other invariants are associated with other possible affordances of the chair.

Table 3 shows a non-exhaustive list of affordances and the invariant characteristics that support them. The list of satisfying objects shown for each affordance illustrates that affordances and their invariants are not perfect selectors – a wide variety of objects, not all good, may support realization of a specific affordance. Affordances are neither good nor bad, nor healthy or unhealthy – they are simply potential uses of an object.

Table 3: Examples of simple affordances and their invariants.

Affordance	Invariant Characteristics	Satisfying Objects
To Walk	Flatness, width, steepness, ...	Path, road, fallen tree, ...
To Sit	Flatness, steepness, height, ...	Chair, bench, stool, table, ...
To Lie Down	Flatness, width, softness, ...	Bed, cot, sleeping bag, ...
To Drink	Taste, smell, viscosity, ...	Water, milk, poison, ...
To Eat	Taste, smell, color, ...	Steak, fruit, okra, plastic, …

Since VEs create an artificial environment, and affordances describe how humans operate and adapt to the real environment, it seems natural to consider basing VE designs on affordances. This approach ought to create interfaces that are more natural, i.e., behave in more understandable and reliable ways, than designs that are not sensitive to their affordances. Natural designs ought to be easier to learn to operate, adapt better to user tasks, and frustrate users less because users would be able to apply the same skills that they have acquired in the real world (Norman, 1988). Many researchers have suggested such an approach (Eberts, 1994; Lintern, 2000; Norman, 1988; Pejtersen & Rasmussen, 1997; St. Amant, 1999). Kensing and Munk-Madsen (1993), in discounting existing HCI methodologies, state that the most important task in HCI design is to focus on models that enhance communication between users and developers. This directly evokes Gibson's claim that affordances can serve as a source of communication between a world and its inhabitants. The desirability of this approach is re-enforced when it is realized that the only way for developers to communicate with users is through the artifacts of their design evidenced in the interface (Anders, 1999).

The question arises as to which affordances are relevant to VE design, and therefore should be represented. For example, eating and drinking are not generally considered tasks suitable for performing in virtual environments. One might begin by considering affordances in the natural environment, however, there presently does not exist any complete, exhaustive characterizations of affordances in the natural environment. While the concept of an affordance is reasonably accessible, the construction of a formal structure of affordances and their inter-relationship is less obvious. In their study of the affordance of graspability, for example Bingham and Muchisky (1992) discuss the problems with trying to define a comprehensive structure of affordances. There is both tremendous functional variability and similarity between closely related terms such as "grasp", "lean", "support", or "trap". It is difficult to cleanly separate these concepts, much less objectively determine whether

19

a particular affordance is being exploited in a particular task. Shaw, Flascher, and Kadar (1995)

classify affordances by the invariants that describe them, specifically geometric (sized to body stature

or characteristics) or kinetic (sized to action capabilities). While this classification provides insights

into the nature of affordances and their invariants, it does not provide helpful insights into the

problem of choosing which affordance(s) to represent in a virtual environment. A different

approach would be to consider the kinds of tasks performed in VEs, and the affordances that would

relate to them. The VE Performance Assessment Battery (VEPAB) provides such a set of tasks.

The VEPAB is a set of tasks designed to support research on training applications of VEs

(Lampton, Knerr, Goldberg, Bliss, Moshell, & Blau, 1994). Table 4 itemizes the affordances that

relate to VEPAB tasks.

Table 4: Tasks in the virtual environment performance assessment battery.

VEPAB Task Category	Corresponding Affordances
Vision	To Recognize
Locomotion	To Walk
	To Fly
Manipulation	To Grasp
Tracking	To Align
Reaction Time	To Choose

The use of affordances in VE design is certainly not a straightforward application. First,

direct perception has a theoretical shortcoming for perception in synthetic environments such as a

virtual environment. Direct perception specifically addresses perception in a natural environment

(which is why the theory is sometimes called Ecological Perception), and denies the ecological

validity of synthetic environments (Gibson, 1979). Second, direct perception offers no method for

applying the theory to interactive system design. Okamoto (1997) states that affordance theory does not seem to be practical, because the theory is so philosophical that designers have no idea how to apply its theoretical statements to the design of human interfaces. Eberts (1994) suggests that deciding on which affordance to associate in a design is an extremely difficult problem. The lack of a practical theory of affordances means there is presently no practical technique for discovering affordances (Fitzgerald & Goldstein, 1997). Bingham and Muchisky (1997) argue that while some researchers have suggested that affordances are revealed in the intrinsic properties of an item, others have attempted to find an affordance in the dynamic behavior of the item. Neither approach has proven generally effective.

As argued in the previous discussion, perception in any environment depends on sensory stimulation in the sensory modalities available to the human. An understanding of the role of sensory stimulation in the realization of affordances could potentially provide an approach to affordance-based design. A number of researchers (Gibson, 1979; Schöner, 1994; Sanocki & Epstein, 1997; Wertheim, 1994; Cutting, Vishton, Fluckiger, & Baumberger, 1997; and Cutting et al., 1999) have pursued the realization of affordances in the natural environment as primarily, if not exclusively, a function of the visual modality. Figure 3 summarizes a number of these studies. For example, Cutting et al. (1999) found that humans make heading judgments independent of object-based motion; instead they depend on visual information such as the displacement direction of the nearest object, inward displacement toward the fovea, and outward deceleration. These studies are valuable in that they demonstrate Gibson's fundamental view of affordances, that the visual field is rich with information about the environment enabling correct perception and action in it. A number of researchers (Gibson & Mowrer, 1938; Runeson & Frykholm, 1981; Lee, Reddish, Lough, & Clayton, 1983; Cohn, Dizio, & Lackner, 2000; Kolev et al., 1996; Warren, 1984; Warren & Whang 1987; Marik, 1987; Bingham & Muchisky, 1992; Oudejans et al., 1996; Turvey, Shocklet, & Carello,

21

1999) have provided research that supports the role of non-visual sensory information in the realization of affordances, at least in natural environments. This body of research demonstrates that the perception of affordances depends on multiple sensory modalities, such as the vestibular and kinesthetic sensory modes. For example, studies such as Warren (1984), Warren and Whang (1987), and Marik (1987) all showed that an understanding of body stature, i.e., self-perception of body stature in the environment was critical to geometric affordances. Lee et al. (1983), Oudejans et al. (1996), and Turvey et al. (1999) showed that kinematic affordances depend on self-perception of action capabilities, i.e., what the individual can do in the environment.

A useful body of research focusing on the exploitation of affordances in the design of synthetic environments exists. Studies such as St. Amant (1999), Gattis and Holyoak (1996), Rensink et al. (1997), Pejtersen and Rasmussen (1997), Gossweiler, Profitt, Bhalla, and Paush (1997), Regenbrecht et al. (1998), Kourtzi and Shiffrar (1997), and Cutting (1997) are chiefly concerned with the role of visual information as it contributes to affordance realization in virtual environments. St. Amant (1999) is the most complete work in this group, presenting an affordance-based approach for designing artificial intelligence planning tools. This work has modeled a planner's user interface as a set of interface operators and preconditions that must exist for a specific action to cause its related affordance to exist. A second group of studies presents evidence that affordance realization in VEs is multimodal (just as it is in natural environments), as typified by Ivanenko, Viaud-Delmon, Sigler, Israel, and Berthoz (1998), Dixon et al. (2000), Stappers (1999), Popescu et al. (2002), Van Der Steen (1996), Kalawsky (2000), Storms, (2002), and Ijsselsteijn et al. (2000). In general, these studies demonstrate that most affordances of interest depend on sensory stimulation other than simply visual, such as kinesthetic and vestibular sensory information. Stappers (1999) is of particular interest, as it provides evidence that affordances that depend on multimodal sensory stimuli are not extant when required modalities are impoverished. For example, Stappers found that VE users did

not rotate their bodies to pass through doorways, as Warren and Whang (1987) found with subjects in the natural environment. Yet, none of these studies explored how to enable the realization of affordances when the sensory modalities required to realize an affordance are impoverished. As suggested by the prior discussion, the problem of impoverished sensory modalities in VEs might be addressed by a sensory substitution scheme. There is currently little, if any, research investigating such sensory substitution schemes in HCI (see Figure 3). Indeed, there is comparatively little research on sensory substitution schemes in natural environments. The research regarding sensory substitution in natural environments arises chiefly from two sources: distracting patients in pain and assisting persons with sensory system defects. In the case of pain distraction, the substitution is to provide sensory stimuli that lead to a perception other than pain. For example, Yamasaki, Kakigi, Watanabe, and Daisuke (1999) and Rode, Salkovskis, and Jack (2001) showed that visual and audio distractions can block pain in some circumstances. In the case of persons with sensory system defects, the substitution is to provide stimuli in an operating modality to replace the defect. Shimojo and Shams (2001) point out that sensory deprivation in early life generally leads to plasticity, in which the cortical area normally devoted to that modality is used by other modalities. Further, Curran, Schacter, and Galluccio, (1999) showed that cross modal priming can assist patients with an impaired ability to convert visual representations of words to speech. These studies suggest that humans are adaptable to sensory substitutions and further, that they can learn to leverage the displaced information to realize affordances. Thus, such schemes could prove useful in VE design to displace missing stimuli that are naturally associated with a given affordance. In order to determine how to develop such schemes, it is first essential to identify how affordances are realized during human perception and potential factors that lead to realization failures.

Affordances

		Virtual Environment (HCI)	**Natural Environment**

Increasing Immersion ⟶

Sensory Stimulus

Visual
- St.Amant, 1999
- Gattis & Holyoak, 1996
- Rensink et al, 1997
- Pejtersen & Rasmussen, 1997
- Gossweiler et al, 1997
- Regenbrecht et al, 1998
- Kourtzi & Shiffrar, 1997
- Cutting, 1997
- Gibson, 1979
- Schoner, 1994
- Sanocki & Epstein, 1997
- Wertheim, 1994
- Cutting et al, 1997
- Cutting et al, 1999

Multi-modal
- Ivanenko et al, 1998
- Dixon et al,
- Stappers, 2001
- Popescu et al, 2002
- Van Der Steen, 1995
- Kalawsky, 2000
- Storms, 2002
- Ijsselsteijn et al, 2000
- Gibson & Mowrer, 1938
- Runeson & Frykholm
- Lee et al, 1983
- Cohn et al, 2000
- Kolev et al, 1996
- Warren, 1984, 1987
- Marik, 1987
- Bingham & Muchisky, 1993
- Oudejans et al, 1996
- Turvey et al., 1999

Sub-stitional
- Gap in HCI Research
- Yamasaki et al, 1999
- Rode et al, 2001
- Shimojo and Shams, 2001
- Curran et al, 1999

Figure 3: A gap in the present HCI research.

Realization of Affordances

Affordances are a model of how animals form percepts, which reflects a natural integration of the variety of sensory stimuli and other factors known to affect perception. A consideration of the factors affecting the realization of an object's affordances provides insights into how they can be designed into objects in a virtual world. Gibson, Riccio, Schmuckler, Stoffregen, Rosenberg, and Taormina (1987) claim that two types of information are required for realizing an affordance: 1) information specifying properties of the thing perceived, and 2) information about the relevant capacity and structural constraints of the perceiver. Along these lines, Allard (1999) has suggested criteria to be met sequentially to validate the existence of an affordance:

1) Subjects must show consistent perceptual judgments of the critical or optimal point of the percept (i.e., a repeatable threshold in terms of sensory stimuli),

2) Subjects must show consistent actions (i.e., a phase transition in behavior made at the critical point), and

3) Perceptual and action points should be the same for each subject, when scaled appropriately to the subject's size.

If the realization of affordances depends on perceptual judgments, then their realization will depend on sensory thresholds. Since Gibson (1979) claims that affordances are perceived in the natural world, they must be sufficient to activate one or more of the sensory systems, i.e., they must arise from sensory stimulation that exceeds the minimum response threshold of the sensory modalities involved. However, Gibson distinguishes between the stimulation of receptors in the sensory system and activation of that system. He provides a useful example explaining his emphasis on the sensory system, versus simply the receptors. In homogeneous darkness, the vision sensory system fails for lack of light, but in homogeneous light (e.g., fog) vision fails for lack of information. Both situations are real failures of the vision sensory system to perceive (Gibson, 1979). Failure for lack of light is an example of failing to exceed minimum response thresholds; failure for lack of information arises even though the minimum thresholds have been exceeded by the stimulation. The implication for the current study is that the sensory stimuli provided in a VE must not only exceed minimum response thresholds, but also be sufficiently organized to be understood.

What about affordances and multimodal stimuli? Warren and Whang (1987) argue that perceiving an affordance implies perceiving the relationship between the environment and the observer's own action system, in particular correspondence between the vision and kinesthetic sensory systems. For example, in the case of an aperture in a wall affording passage, such as a

doorway, they empirically determined that the ratio of aperture width to shoulder width should be 1:1.3 or greater to realize an affordance of easy passage. Since this study investigated passage as a visually guided action, the aperture was certainly visible. But one's shoulders are not completely visible – at best they fall in the peripheral field of vision. Indeed, the perception of the passability affordance depends on at least two sensory modalities, vision (for aperture width) and kinesthetic (for body dimensions), as well as additional factors such as attention and motivation, and the human's action capability of walking. This raises a challenge for VE design, that if an affordance that depends on multiple sensory modalities is to be realized, then the VE design must present sufficient information in the required modalities, or substitute sufficient information in other modalities. The following discussion looks more closely at how such realization occurs.

A synthesis of the affordance literature yields six principles about how the various factors involved in perception are integrated into a percept via the realization of an affordance. Each of these assertions about the realization of affordances provides implications for VE designers seeking to enable correct perception.

Affordances depend on objects in the environment. Self-evidently, different object properties/behaviors result in different affordances. This is the very essence of what it means for objects to be different. A chair is different from a wall because it provides different affordances. The organism can perceive the same affordance from multiple objects, but some objects provide a stronger (better fit) affordance than others (St. Amant, 1999). For example, in a room of varying height chairs, the one closest to the observer's knee height will best afford sitting. Shorter chairs may well be treated as stools affording climbability. The specific properties of objects in the environment that evoke particular circumstances, such chair height or passage width, may be thought as evoking circumstances. This can be thought of as a "goodness of fit" function for affordances. Designers should thus try to endow objects with properties that are relevant to an

individual's purpose within a VE system and thus afford desired skills and appropriate behaviors. In

terms of Figure 1, this means that the selection of specific objects and properties in a VE design

determines the affordances that may be realized by VE users.

Affordances depend on the organism's action capabilities. Obviously, different action

capabilities result in different affordances. For example, the surfaces that afford walking to quad-

pedal creatures (e.g., a horse) are different than those that afford walking to bipedal creatures (e.g.,

humans). Animals with relatively rare action capabilities such as flying are afforded different things

by their environment than animals that do not possess this capability. Specific to humans, Oudejans

et al. (1996) showed that the affordance of catchability related to kinematic action capabilities such

as speed and acceleration. Designers should provide affordances that engender appropriate action

to attain relevant goal-oriented behavior. In terms of Figure 1, this means that the feedback loop,

which begins with an actor making and executing decisions, which causes change in an environment,

and which are then observed by the actor, affects the realization of affordances.

Affordances depend on physical characteristics of the observer. Warren (1984) showed

that leg length related to realizing climbability. Warren and Whang (1987) showed that realization of

passability related to shoulder width. Marik (1987) showed that changes in participant's height

affected affordances such as sitting and climbing. Bingham and Muchisky (1992) showed that

realizing graspability related to hand size. Taken together, these studies provide evidence that

humans adjust invariants based on their understandings of their body stature in the environment.

Further, Marik's (1987) experiment showed observers can rapidly and accurately adapt to at least

some changes in their stature (in this experiment, specifically height), when they become aware of

them. Marik varied subjects' height by having them stand and walk on wooden blocks, and showed

that subjects realized a different affordance after a period of accommodation. The issue for VE

system designers thus becomes whether or not one should somehow represent the physical

characteristics of observers in order to engender use of affordances. In terms of Figure 1, this means that a user's understanding of body stature in an environment affects the affordances that the user can realize in the environment. Further, Marik's experiment suggests that physical characteristics have persistence in the stimulus integration mechanism, and do not simply arise from sensory stimuli.

Affordances depend on the organism's sources of sensory stimuli. Different senses result in different affordances. Animals such as bats and dolphins, with strong auditory sensory systems are afforded different things by their environment than animals without auditory systems such as snakes. Stephens and Banks (1987) showed that the ability to detect differences in spatial contrast (crucial to object recognition) changes as infants age, suggesting that changes in underlying neural mechanisms underlie the ability to perceive these differences. As humans inherently use multiple senses to perceive affordances, the issue for VE system designers becomes how to develop multimodal representations that elicit such direct perception in virtual worlds. In terms of Figure 1, this means that the specific senses available, or not available, to the user in a VE bound the affordances that a user may realize in the environment.

Affordances depend on integration of multimodal sensory stimuli. Gibson (1979) recognized the cross modal perception that occurs between vision and kinesthetics, calling it "visual kinesthesia." Van Der Steen (1996) suggests that a multimodal perception model is needed to describe the dynamics of perceived self-motion in a virtual environment. Wertheim (1994) argues that visual-vestibular interaction is crucial for correct perception in ecologically valid environments. Marik (1987) showed that the affordances of sitting and climbing are affected by visual information about chair or step height, and vestibular information about participant's leg length and eye height. One may deduce from such research such that affordances are perceived because of cross modal stimulation, and further that affordances are a way of describing how an organism integrates its

28

knowledge of its own action capabilities. Virtual environment designers need to understand the types of cross-modal interactions that transpire during direct perception and the possible sensory substitution schemes that can be enacted when a critical sense cannot be represented in a virtual world.

The argument that affordances may be cross modal is not prevalent in the affordance literature, which is fixated on visual perception. The present lack of research on multi-sensory perception is unfortunate, because there is evidence that much of perception depends on cross modal sensation. Kalawsky (2000, p.2) states, "Traditionally, sensory modalities have been investigated in isolation from one another." He argues that different kinds of interactions involve different sets of sensory modalities, rather than modalities working in isolation. For example, he suggests that four senses bear on orientation: visual, tactile, proprioceptive, and vestibular.

The premise that the perception of affordances depends on integration of multimodal stimuli could represent a problem for perceiving affordances in present day virtual environments. Indeed, Stappers (1999) showed that the affordance of passability was not correctly perceived in a VE, possibly because shoulder width was not perceived. However, it may be possible to substitute information naturally presented via non-visual modes with that represented via the visual mode in a virtual environment. For example, Runeson and Frykholm (1981) showed that observers could accurately estimate the weight of an object simply by viewing a small number of lights worn on significant points on a human form picking up the object. Therefore, designers may be able to exploit the existing strong correlation between visual (e.g., light points) and non-visual (e.g., the weight of an object) information to replace missing sensory information in a virtual environment. Virtual environment designers thus need to determine the key physiological factors (e.g. eye-height) that drive sensory viewpoint and how to appropriately represent these factors in the virtual world.

This has direct implications for Figure 1, in that a user's integration of body stature, action capabilities, and available sensory modalities also affects the affordances that the user may realize.

Affordances arise as the organism learns to act within its environment. Eleanor J. Gibson et al. (1987) showed that transversability of different surfaces for infants depended on the mode of locomotion (crawling or walking) and that the pattern of experimentation to learn what a surface afforded differed between crawlers and walkers. Marik (1987) showed that experience with changed body stature requires a period of accommodation during which the new stature is experienced. Experience arises as the organism explores its environment. These findings have significant implications for the design of virtual environments. New users in a virtual world are comparable to infants, except that they come to the virtual world with a wealth of experience. VE designs that exploit what users have already learned should require less training

Eleanor J. Gibson (1987) argues that there are eight well-substantiated conclusions about perception in infants that have implications for theories of perception.

1) Perception is active, exploratory, and motivated even in the neonate.

2) Perception [in infants] is externally directed toward distal sources of information.

3) Infant perception not only uses but also depends on information given in motion.

4) Perception [in infants] is of a three-dimensional world.

5) Perceptual "constancy" for various object properties exists before reaching, grasping, and handling objects are manifest [in infants].

6) Perception (in infancy) is coherent; that is, structure is detected.

7) Perception [in infants] is inter-modally coordinated.

8) Perceptually guided actions are organized and flexible [in infants], not reflexive or
    mechanical stimulus-response sequences.

Freedland and Dannemiller (1987) showed that motion–sensitive mechanisms responsive to small spatial displacements are present at five months of age. They conclude that image motion is a rich source of information about the layout of surfaces in an environment. Kellman, Glietman, and Spelke (1987) showed that infants as young as 16 weeks distinguish optical displacements given by their own motion from displacements given by moving objects, and use only the latter to perceive the unity of partially occluded objects. They asserted that object perception therefore depends on registration of the motion of surfaces in a three-dimensional layout. Kellman and Short (1987) showed that continuous perspective transformations, given by object or observer movement, are the information basis for early three-dimensional form perception. Detecting form in stationary views is a later development. Kourtzi and Shiffrar (1997) for example argue that motion plays a crucial role in object recognition. In terms of Figure 1, this means that there is a feedback loop from decision-making and execution based in experience that affects the affordances that can be realized.

The conclusion drawn on the foregoing discussion is that affordances are realized through integration of environmental stimuli and state stimuli interacting with experience gained through decision making, which in turn affects an individual's knowledge of internal state, action capabilities, and body stature in the environment, just as illustrated in Figure 4.
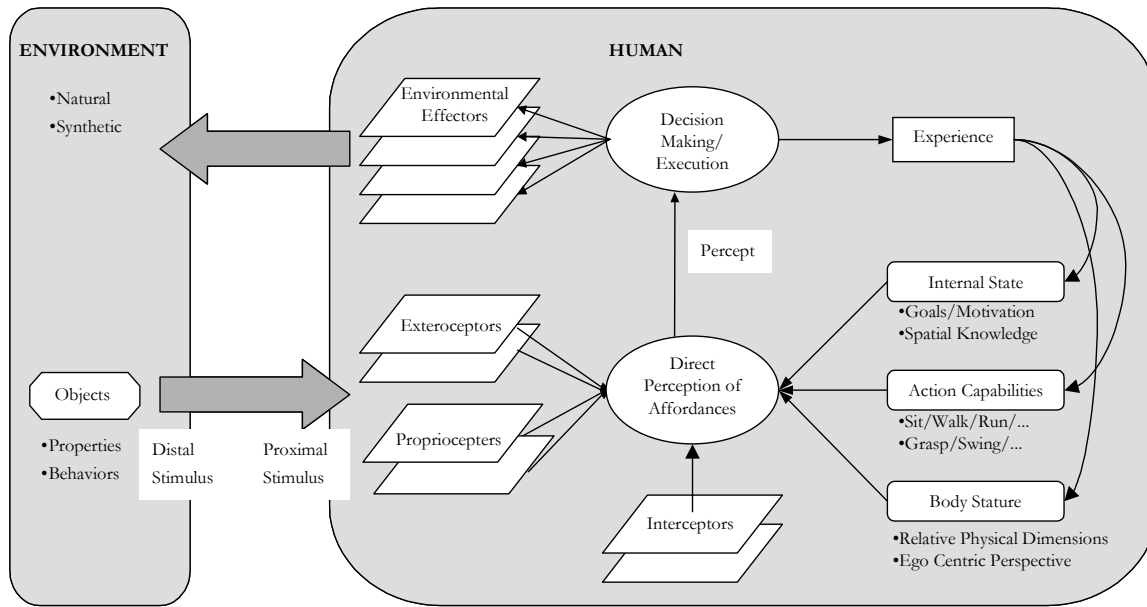
Figure 4: Realization and exploitation of affordances.

Realization Failures

Affordances are not correctly realized in all circumstances, even in the natural environment. Gibson (1979) discusses this problem in the context of illusions, and defined circumstances that do not permit the correct perception of affordances as ecologically invalid. Ecological invalidity may be said to be a violation of the environment (Kennedy, 1974). Designed environments, such as VEs, are not intrinsically ecologically valid, and so may not support the realization of affordances as desired by their designers. While researchers have discussed the problem of ecological invalidity in general terms, Figure 4 presents a context for decomposing the causes of such invalidity and thus, in turn, discovering guidance for VE designers.

The most basic source of failure to realize affordances is an inaccurate or insufficient sensory stimulus, i.e., one below the modality's response threshold (see Figure 2). Rose, Jankowski, and Senior (1997) showed that infants are capable of recognizing line drawings missing as much as 66%

of their contour. In this same study, infants failed to discriminate between two extremely impoverished figures, i.e. more than 66% missing, because of inaccurate sensory stimuli. Thus, to realize the perception of affordances, stimuli must be above the appropriate sensory modality threshold. In terms of Figure 4, this would be a failure of the proximal stimuli to activate the sensory system.

A closely related source of realization failure that is especially pertinent to VEs is the absence or inaccuracy of required multimodal sensory stimulation to realize an affordance. The realization of affordances can depend on multimodal sensory stimulation. For example:

- Warren and Whang (1987) found in a study of passability, that when approaching a doorway whose ratio of width to shoulder width was less than 1:1.3 that subjects would rotate their body. This is an indication of the kinesthetic and visual sense interacting with the action of walking.

- Wertheim (1994) argues that the vection created with an optokinetic drum must involve extra retinal signals, namely vestibular afferents. This argument led Wertheim to argue more generally that visual-vestibular interaction is crucial for correct perception in ecologically valid environments.

- Oudejans et al. (1996) presented a study on the catchability of fly balls measuring the ability of subjects to judge whether they could catch balls thrown at various distance from the subject. This study demonstrated that perceiving the affordance of catchability depends on kinematics of the subject's body, as well as the movement of the ball, by showing that the ratio of balls judged catchable to those actually catchable varied with the dynamic information available to the observer. Subjects' judgment error was almost halved when the subjects were permitted to move before judging a ball as catchable. This suggests that the judgment as to a

33

ball's catchability depends on dynamic information arising from the kinesthetic and vestibular senses, as well as information arising from the visual sense.

All of this research suggests that correct realization of these affordances may be perceived cross modally, in particular crossing between the visual sensory system and other sensory systems (e.g., vestibular, kinesthetic). This poses a problem for VE design because even though their stimulation is required for realization of some affordances, there exists no reliable and economical way of providing artificially simulated propriocepters and interceptors (Stuart, 1996). Instead of receiving artificial simulation correlated with the virtual environment, users experience continual and generally contradictory stimulation from the natural environment. In terms of Figure 4, this would be a breakdown of the interface between propriocepters and interceptors and direct perception.

Another source of realization failure may be inadequate perception of body stature in the environment. Gibson (1979) suggested that environmental properties have to be measured relative to the animal, without specifying how this relationship is defined. Warren (1984) argues that this is a visual perception, however acknowledges that what must be occurring is perception of environmental properties relative to the observer's capabilities. He proposed that the critical (maximum) and optimal values of an environmental property, relevant to performing an action, are an invariant proportion of some aspect of the actor's body scale. He demonstrated this by showing that the climbing affordance on stairs is influenced by visual information about the height of the step and internal state information about the length of the observer's leg. Marik (1987) extended Warren's finding by demonstrating that the critical boundaries for the affordances of sitting and stair climbing are scaled with reference to the actor's eye-height. Warren and Whang (1987) found that perception of the passage affordance depends on both visual information about aperture width and internal knowledge of shoulder width. This study presented doorways of varying widths to subjects, and measured their response. At shoulder widths to doorway ratios of less than 1:1.3, subjects

perceived insufficient clearance, and rotated their bodies to proceed through the opening. These findings are significant for understanding how affordances may be perceived in VEs, because it indicates that information about body stature is required if a user is to realize correct affordances, and because VE designs frequently do not provide users with information about their own stature (Anders, 1999). In terms of Figure 4, this would be a loss of the information represented by "stature" in the environment block.

A final source of realization failure particular to designed environments such as VEs is inadequate perception of action capabilities in the environment. For example, VEs often do not match the real world in terms of what can be done. Indeed providing different action capabilities is one of the motivations for using virtual environments. Although VEs can evoke an immersive experience, this does not lead automatically to a natural interface. To experience a natural interface, the user should be able to perceive what could be done via the interface. St. Amant (1999, p. 342) for example argues that:

> "Users only rarely encounter problems in using specific widgets, and remedies at the given level of abstraction can only provide a limited benefit. Problems more often arise at a conceptual level. What is it possible to do in the interface? Why can't a given operator be executed in the current state? How can one reach a desired goal? "

Since VEs represent a kind of reality and seek to immerse their users in that reality, users have a reasonable expectation that the environment behaves like reality or in easily understandable deviations from reality. However, the VE interface design, not physics, defines what the organism is capable of doing (moving, orienting…), thereby defining the context for affordances included in the environment. In the example of the passability affordance study (Warren & Whang, 1987), it is not clear that a VE user would know that body rotation is possible in any particular interface, much less necessary or helpful to gain passage. In the example of the catchability study (Oudejans et al., 1996), it is possible that VE users may not know how to maneuver so as to catch something if locomotion

is represented radically different from the nature environment. As a result, users cannot depend on their experience based expectations about manipulating their environment. In terms of Figure 4, this would be a loss of the information represented in the action capabilities block.

Figure 5 illustrates these potential breakdowns in the realization of affordances in virtual environments. To summarize, the types of realization failures that may occur in VE include:

1) Inaccurate or insufficient sensory stimuli,

2) Absence or inaccuracy of required multimodal sensory stimulation,

3) Inadequate perception of body stature in the environment, and

4) Inadequate perception of action capabilities in the environment.
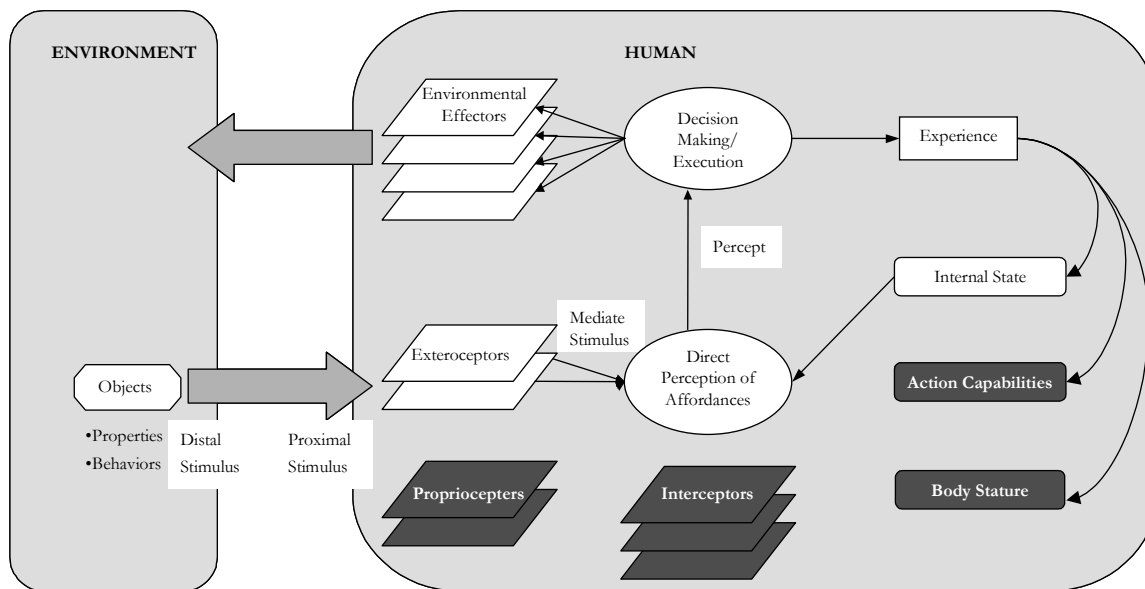
Figure 5: Potential failures in realizing affordances in virtual environments.

Sensory Substitution via Affordance-Based Designs

Breakdowns in the realization of affordances in VEs can potentially be overcome by 1) correlating sensory stimuli to the experience represented in the virtual world, 2) determining a particular modality is irrelevant to the experience, or 3) substituting information in another modality for missing modalities. The latter approach, sensory substitution schemes, may have the greatest potential as it is not limited by technology (as is the first approach) and does not require diminishment of an experience (as does the second approach). Sensory substitution schemes could potentially be used to replace missing stimuli required to evoke the realization of affordances. VEs create an artificial world, whose design defines what the user can do and the sensory stimuli to be provided. As such, VEs provide some but not all of the sensory stimuli of reality. Non-visual mode stimuli in particular are missing in VEs (e.g., kinesthetic, vestibular). As a result of these inaccuracies and absences, a user's ability to correctly perceive available action capabilities (what the user can do in the environment) may be depleted. Furthermore, representations of user characteristics (e.g., size, strength) that would normally be understood through kinesthetic and vestibular stimuli are arbitrary and typically unrelated to the user's "real" capability. VE designers, by selecting action capabilities to support and object/properties/behaviors to represent, can choose which affordances the VE will present. However, this process is often not deliberate. Thus, it is important to note that the VE, like any other environment, will present affordances whether or not they are consciously designed.

It may be possible to provide missing non-visual sensory stimuli, and hence enable perception of specific affordances by manipulating the objects/properties/behaviors selected for representation in a virtual environment. More specifically, it may be possible to realize correct perception by overloading (i.e., above threshold) visual stimuli that enable perception of particular affordances.

Evidence that Sensory Substitution Schemes Can Succeed

There is evidence that sensory substitution schemes can lead to correct perceptions, even though the current state of multimodal modeling in VE design is rudimentary (Popescu et al., 2002). First, consider that all perception is multimodal, not just complex reactions to an environment (Storms, 2002). Bregman (1990) believes that auditory and visual modalities interact in order to specify the nature of certain events within a perceiver's environment. Eimer (2001) asserts that cross-modal links exist in spatial attention between vision, audition, and touch, and that emerging evidence suggests that cross modal links in spatial attention affect sensory-perception stages, but have less impact on later post-perceptual stages. The body of evidence in the literature clearly indicates that under certain conditions, auditory-visual perceptual phenomena do exist (Storms, 2002). The implication for the present study is that since sensory modalities are complementary, they may be to some extent redundant and therefore replaceable by stimuli in other modalities.

Next, consider the evidence that there may be underlying neurological factors that determine perception more than the specific sensory modalities involved. Specifically, if the brain is structured to favor perceptions arising from multimodal stimuli, then correct perception may depend on multimodal stimuli. Stein and Meredith (1993, p. 172) found neurological evidence for this position, based primarily on their study of cats. They conclude:

> "... the spatial register among the receptive fields of multisensory neurons and their temporal response properties provide a neural substrate for enhancing responses to stimuli that co-vary in space and time and for degrading responses that are not spatially and temporally related."

The implication for the present study is that since brain structure may be favorable toward perception of multimodal stimuli, then in environments where specific sensory modalities are impoverished such as VEs, correct perception may require stimuli that substitute for improvised modalities.

Next, consider that there is evidence that stimulation in one modality can complement or distract from stimulation in other modalities. Curran et al. (1999) provide evidence for cross modal priming, specifically that verbal data primed the perception of subsequent visual images. Henneman and Long (1954) indicate there has been very little experimental evidence comparing audition and vision as channels for data presentation and conclude that most auditory-visual inter-sensory studies have focused on sensory thresholds as opposed to supra-threshold levels that typify actual perceptual phenomena. Rode et al. (2001) showed that an audio distraction significantly lowered perceived pain, as measured by subjective report and improvement on a muscle stamina task. Spence and Driver (1997) argue that people can monitor cross modal stimuli as effectively as a single stimulus. The implication for the present study is that the ability for stimuli in some modalities to distract from stimuli in other modalities suggests that cross modal sensory substitution schemes can be an effective HCI approach, within yet to be determined limits.

Finally, Shimojo and Shams (2001) note that the direction of cross-modal interactions has been thought to be determined by the relative appropriateness of the modalities involved in a given task, but that emerging evidence is that the direction depends at least in part on the structural (spatial versus temporal) nature of perceived stimuli. They, along with other researchers such as Monder and Amirault (1998), note the strong association between spatial perceptions and visual stimuli, and temporal perceptions and auditory stimuli. Shimojo and Shams (2001) suggest that the brain may accept stimuli in a modality other than the natural one, if the underlying spatial-temporal structure of the stimuli is retained. This is similar to the argument in favor of stimulus-response compatibility advanced in for example Eberts (1994). In general, relationships between stimuli and responses are compatible when they facilitate correct action. The example cited in Eberts is for a stovetop design, in which the controls are laid out in the same pattern as the stove eyes. The

implication for the present study is that substitution schemes should match stimuli to the spatial-temporal nature of perception when substituting one modality for another.

The foregoing discussion presents the general case that substitution schemes may succeed, however, the specific form of the substitution scheme has not been considered.

Determining which Sensory Substitution Schemes to Explore

There are many different conceivable sensory substitution schemes; however, the literature provides some guidance on which is likely to succeed. First, consider that the only mechanism that a VE designer has for communicating with users is through the proprieties of objects represented in the virtual environment. Therefore, the only possible sensory substitution schemes will be ones that exploit the exterocepter (i.e., vision, audition) or propriocepter (i.e., cutaneous, gustation, olfaction) sensory systems.

The most obvious scheme would be to provide visual cues to substitute for missing sensory stimulation. This is because:

1) Visual stimuli in VEs are already available and powerful,

2) The visual sensory system has the broadest band input to the brain (Sharma et al., 1998), and

3) The visual dominance effect.

Storms (2002) suggests that substitution schemes based on visual cues should be readily perceived. Unless there are significant differences in the intensities of information gathered via different modalities, visual stimuli have been found to have a greater influence on perception via other modalities, as compared to the influence of other modalities on the visual sense (Stein & Meredith, 1993). Wickens (1992, p.108) explains visual dominance by stating: "if visual stimuli are appearing at the same frequency and providing information of the same general type or importance

as auditory or propriocepter stimuli, biases toward the visual source at the expense of the other two (auditory and propriocepter) will be expected." Cohn et al. (2000) present an example of how a visually pure environment can elicit a visual reflex rather than a straightforward perception of the sensory data. More specifically, they showed that visual information about body motion alone is sufficient to elicit directionally appropriate Coriolis compensations (i.e., the automatic compensation made in reaching that counters Coriolis effects). Srinivasan, Beauregard, and Brock (1996) demonstrated the effect of visual dominance on haptic perception. In this experiment, participants had to discriminate the stiffness of two virtual springs when provided with independent visual and haptic feedback about their stiffness. When visual stiffness stimuli conflicted with haptic stiffness stimuli, participants judged stiffness consistent with the visual stimuli in preference to haptic feedback. Finally, Ivanenko et al. (1998) showed that humans exposed to a VE undergo adaptations at the sensory level including adaptations of the vestibulo-ocular reflex and angular displacement perception, and that these adaptations may be independent. This evidence that visual stimuli can evoke a reaction in other sensory systems, suggests that visual stimuli alone may evoke a perception comparable to that evoked by multimodal stimuli in the natural environment.

However, vision is not the dominant sense in every circumstance; therefore substitution schemes other than purely visual stimuli should be considered. During signal detection (temporal in nature and typically associated with sustained attention or vigilance), the auditory channel proves dominant over the visual channel, which is why warning signals are typically produced with auditory devices (Storms, 2002). There is also evidence that the intensity of visual images can be enhanced by audio stimuli (Shimojo & Shams, 2001). It is known that the presentation of an audio cue reduces the time required for visual searches (Flanagan, McAnally, Martin, Meehan, & Oldfield, 1992). This suggests that tasks thought of as primarily dependent on visual perception may be further enabled by auditory perception.

What about sensory substitution schemes exploiting proprioceptors? There is very little research into providing sensory stimulation for gustation and olfaction, but somewhat more for haptic stimulation. Proffitt and Kaiser (1995) provide an example of haptic dominance. They asked participants to estimate the incline of a hill while provided with audio, visual, and haptic stimuli, and the most accurate estimates resulted from the haptic. In general however, there is little evidence encouraging approaches exploiting proprioceptors (Popescu et al., 2002). Therefore, sensory substitution schemes may best be based on exterocepters (i.e., visual, auditory), instead of proprioceptors.

A final potential substitution scheme, in addition to visual, audio, and haptic, is a combined approach. Several authors have suggested that sensory substitution schemes should map spatial information to visual substitution cues, and temporal information to auditory cues (Popescu et al., 2002; Shimojo & Shams, 2001). This suggests that the structure of the information to be perceived might indicate the best substitution scheme.

Figure 6 illustrates the fundamental constraint of any sensory substitution scheme, namely that the substitution stimuli can only arise from the properties and behaviors of objects represented in the virtual environment. In addition, the substitution stimuli in successful sensory substitution schemes must:

- Replace sensory modalities not represented in the virtual environment,

- Outweigh natural stimuli not correlated with the virtual environment,

- Exceed response thresholds in the modality used for the substitution.
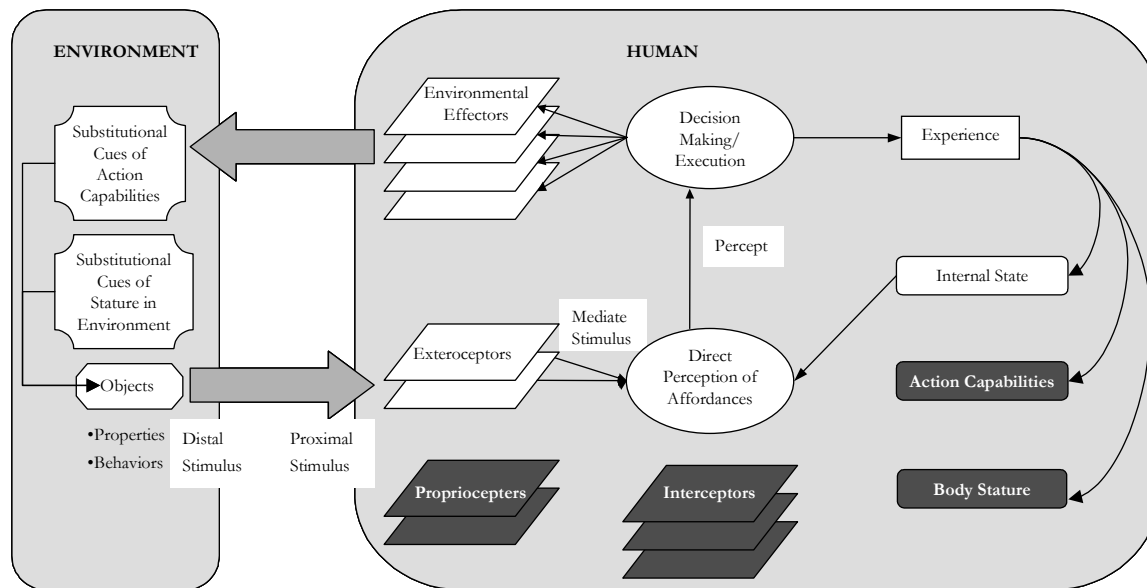
Figure 6: A conceptual model for VE designs enabling the realization of affordances.

One way to select a substitution scheme is to test it to see if it enables correct perception, in terms of enabling the realization of affordances. There are a large number of conceivable affordances against which sensory substitution schemes could be tested for enabling correct perception. Instead of considering every one of them, it is possible to reduce the number that should be considered to a reasonable few, based on the understanding of affordances developed in the foregoing discussion. Recall Shaw, Flascher, and Kadar's (1995) classification of affordances as geometric (sized to body characteristics such as stature) or kinetic (sized to action capabilities). This suggests that a good test suite of affordances should include at least one geometric and one kinetic affordance. Further, since one of the chief advantages of VEs is that they can enable body statures and action capabilities that do not occur in the natural environment, the test suite should include unnatural body statures and action capabilities, e.g., flying. This suggests a test suite of three affordances:

1) Passability

2) Catchability

3) Flyability

Realization of Passability

A critical component of learning to act within an environment is exploration, which requires wayfinding through the environment (Gibson, 1979). Further, as users often become lost while exploring a VE (Ellis, 1993; Jul & Furnas, 1997), some means of better affording wayfinding may substantially enhance VE task performance. In contrast, Cutting et al. (1999) assert that wayfinding through situations in the natural environment quickly and safely is a basic and routine task. Passability, the realization that a passageway affords movement by the human through it, is a basic affordance required for wayfinding through cluttered environments. Warren and Whang (1987) conducted a series of experiments measuring participants' responses to various passageway sizes. They determined that the invariant for free walking passage was the ratio of passageway width to shoulder width. The critical value, i.e. value at which behavior changed from free walking to rotation of shoulders, was 1:1.3, which defines an invariant in terms of body stature.

It is not evident that VEs enable the realization of passability. Stappers (1999) for example found no evidence that users in a VE rotated their shoulders in response to various passage widths as Warren and Whang (1987) found in the natural environment. This failure to realize passability is anticipated because of impoverished, absent, or conflicted cues in VEs as shown in Figure 5. The stimulation integration process depends on three key sources of information in order to realize the passability affordance. First, a goal or motivation to move must exist. Next, visual stimulation arising during the process of locomotion must provide sufficient stimulation of a passageway. Finally, knowledge of body characteristics, or ongoing kinesthetic and vestibular stimulation, must

provide information about body stature. The stimulus integration mechanism arrives at the percept

of the passability affordance by scaling shoulder width to passage width, when motivated by the goal

to move through the passage. The realization of the passability affordance can be detected by

observing the decision made by a subject when arriving at a passage entrance, either to:

- proceed without rotation (ratio is > 1:1.3), or

- rotate (ratio < 1:1.3), or

- stop (ratio < some unknown small value)

As Table 5 indicates, three key sources of information for realizing the passability affordance

are available in a natural environment, but information about body stature is impoverished in a

virtual environment. A VE user's sense of their body stature, which arose through experience in the

natural world, is not valid in the virtual world. Sensory systems such as propriocepters and

interceptors that a user might use to develop kinesthetic or vestibular information about body

stature in an environment are not available to users in typical VEs and further, users may be

provided with conflicting information from their stature in the natural environment.

Table 5: Information required for the realization of passability.

Required information	Enabling information in the natural environment	Enabling information in a virtual environment
Desire to move through passage	Internal state information which includes goals, motivation	Internal state information which includes goals, motivation
Passage width	Visual	Visual
Shoulder width	Arises from experience and ongoing kinesthetic and vestibular mode stimulation	Impoverished, absent, and/or conflicted in a VE

Impoverished, absent, or conflicted information needed to realize the affordance of passability in a VE might be provided by a sensory substitution scheme. To be effective, the substitution would have to replace missing exterocepters (i.e., visual, auditory cues), interceptors (i.e., kinesthetic, vestibular cues), and propriocepters (i.e., cutaneous cues) associated with traversal through a passageway, as well as overwhelm any conflicting cues from the natural environment. Due to visual dominance (Storms, 2002) and the strong association between spatial perception and visual stimuli (Shimojo & Shams, 2001), visual cues for body stature may be able to substitute for absent multimodal sensory stimulation and body stature information, thereby enabling the realization of the passability affordance in virtual environments.

Visual dominance refers to the preeminent influence that visual stimuli have on perceptions. Stein and Meredith (1993) note that unless stimuli in a competing sensory modality are especially intense, visual stimuli provide the basic influence as to how sensory stimulation are interpreted. Thus, it may be possible to leverage a visual cue representing shoulder width to dominate other sensory stimulation, such as kinesthetic and vestibular cues about stature in the natural environment, by exploiting the visual dominance effect. In a similar vein, since passability is a geometric affordance, its realization is enabled by a spatial perception, namely the comparison of shoulder width to passage width. Popescu et al. (2002) notes the strong correlation between visual stimulation and spatial perceptions. A visual cue representing shoulder width would exploit the relationship between spatial perception and visual stimuli.

In terms of the realization process described for passability, such a visual cue in a VE would provide the impoverished, absent or conflicted information about body stature in the virtual environment. The visual cue could potentially provide a valid source of information about the user's

46

body stature. Armed with this additional information, a user's stimulus integration mechanism would arrive at the percept of the passability affordance by scaling the visual cue about shoulder width to passage width, when motivated by the goal to move through a passage. Visual cues then, for the specific affordance of passability, may be able to meet the previously described requirements for a successful sensory substitution scheme: replacing sensory modalities not represented in a VE by exploiting the visual dominance effect, outweighing natural stimuli not correlated with the VE; and exceeding response thresholds in the modality used for the substitution. These observations lead to the following hypothesis.

Hypothesis: Visual cues for body stature substituting for absent multimodal sensory stimulation and body stature information can enable the realization of the passability affordance in VEs, as confirmed by testing for the ratio of 1:1.3 for comfortable passability.

It is not evident what form these visual cues should take. While Warren and Whang (1987) assert that shoulder width is the required body stature information to realize passability, they and other researchers such as Marik (1987) suggest that realization of the affordance may be scaled to other body stature information such as eye height. Also, it is possible that a combination of body stature information is required (e.g., shoulder width, eye height). Finally, it is not known how extensive the cue would have to be, in terms of visual thresholds. For example, if the cue is a representation of shoulder width, it is not known whether the cue has to be a realistic representation of shoulders on a body form, or a simple cross bar on a stick. These open questions raise the need to identify which visual cues of body stature provide the most effective substitution for realization of passability.

Hypothesis: An appropriate minimal form for visual cues of body stature can be found, as confirmed by measuring threshold responses to a variety of cues.

Realization of Catchability

A critical ability in any environment is interaction with other moving objects, whether animate or inanimate (Gibson, 1979). As an example, Oudejans et al. (1996) investigated the affordance of catchability, in the particular situation when movement is required to intersect an object's path, as opposed to simply reaching. They demonstrated that realization of this kinematic affordance depended on knowledge of action capabilities, in contrast to previously demonstrated geometric affordances, such as passability, that depend on knowledge of stature in the environment. Oudejans et al. demonstrated that the specific kinematic action capability information required was knowledge of self-locomotion, namely velocity and acceleration. This study found that the ratio of the range at which balls were actually catchable to the range at which balls were judged catchable was 1:1.2, which is a measure of the subject's perception. An observer can realize catchability if the observer can scale the action capability of self-acceleration to the object's motion, as opposed to scaling the body stature, i.e., of shoulder width to the passage width, as was the case for passability. Catchability depends therefore not only on spatial but also temporal relationships.

It is not evident that VEs enable the realization of catchability. Indeed, the failure to realize catchability is anticipated because of impoverished, absent, or conflicted cues in VEs as shown in Figure 5. The stimulation integration process depends on seven key sources of information in order to realize the catchability affordance. First, a goal or motivation related to catchability must exist, for example a desire to catch a ball. Next, sensory stimulation in the environment must provide information about the ball's position, velocity, and acceleration. Acceleration is negligible assuming un-powered flight and short flights where air resistance is not a factor. Next, sensory stimulation in the environment and in the subject must provide sufficient indication of self-position, self-velocity, and self-acceleration, so that the subject may move toward the ball's path. The stimulus integration mechanism arrives at the percept of the catchability affordance by scaling the self-acceleration action

48

capability to the vertical optical acceleration of the ball. Vertical optical acceleration is the acceleration of the projection of the center of the ball on a vertical image plane, and specifies the direction that the observer should accelerate to intercept the ball's flight. Catchability is realized when a near zero vertical optical acceleration can be achieved, when motivated by the goal to catch the ball. Near zero acceleration means acceleration below the detection threshold. Note here that the affordance under consideration is catchability, which is a judgment as to whether a ball is catchable or not, not the actual hand-eye coordination of grasping a ball in flight. The realization of the catchability affordance can be detected by observing the decision made by a subject when presented with thrown balls, either to continue to pursue catching the ball, or to stop.

Table 6 indicates that seven key sources of information for realizing the catchability affordance are available in a natural environment, but information about self-acceleration is impoverished in a virtual environment. A VE user's sense of action capabilities, which arose through experience in the natural world, is not valid in the virtual world. Sensory systems such as propriocepters and interceptors, which a user might use to develop kinesthetic or vestibular information about action capabilities in an environment, are not available to users in typical VEs and further, users may be provided with conflicting information via kinesthetic and vestibular senses from the natural environment.

Table 6: Information required for the realization of catchability.

Required information	Enabling information in the natural environment	Enabling information in a virtual environment
Desire to catch the ball	Internal state information which includes goals, motivation	Internal state information which includes goals, motivation
Ball position	Visual and Auditory	Visual and Auditory
Ball velocity	Visual and Auditory	Visual and Auditory
Ball acceleration	Visual and Auditory	Visual and Auditory
Self-position	Visual	Visual
Self-velocity	Arises from experience and ongoing kinesthetic and vestibular mode stimulation	Impoverished, absent, and/or conflicted in a VE
Self-acceleration	Arises from experience and ongoing kinesthetic and vestibular mode stimulation	Impoverished, absent, and/or conflicted in a VE

As was the case for passability, impoverished, absent, or conflicted information needed to realize the affordance of catchability in a VE might be provided by a sensory substitution scheme. To be effective, the substitution would have to replace missing exterocepters (i.e., visual, auditory cues), interceptors (i.e., kinesthetic, vestibular cues), and propriocepters (i.e., cutaneous cues) associated with accelerating to catch a ball, as well as overwhelm any conflicting cues from the natural environment. Due to visual dominance (Storms, 2002), the ability for auditory stimuli to intensify visual stimuli (Shimojo & Shams, 2001), and the strong association between temporal perception and auditory stimuli (Shimojo & Shams, 2001), a combination of visual and audio cues for action capabilities may be able to substitute for absent multimodal sensory stimulation and action capability information, thereby enabling the realization of the catchability affordance in virtual environments.

Visual cues representing self-velocity and self-acceleration may dominate other sensory stimulation, such as kinesthetic and vestibular cues about self-acceleration in the nature environment, by exploiting the visual dominance effect. Since both self-velocity and self-acceleration have a time component, they are temporal perceptions. Storms (2002) and Popescu et al. (2002) note the strong correlation between temporal perception and auditory stimulation. Auditory cues representing self-acceleration and self-velocity would exploit the relationship between temporal perception and auditory stimuli. Finally, a combination of visual and auditory cues could exploit the reinforcing and intensifying effect between visual and auditory stimuli noted by Shimojo and Shams (2001), and thereby may enable realization of the catchability affordance.

In terms of the realization process described for catchability, visual and auditory cues in a VE would provide impoverished, absent or conflicted information about self-position in the virtual environment. In addition, visual and auditory cues could potentially be combined to provide a valid source of information about a user's action capability. Armed with this additional information, a user's stimulus integration mechanism would arrive at the percept of the catchability affordance by scaling cues about locomotion action capabilities, when motivated by the goal to catch the ball. Visual and auditory cues then, for the specific affordance of catchability, may be able to meet the previously described requirements for a successful sensory substitution scheme: replacing sensory modalities not represented in a VE by exploiting the visual dominance effect, outweighing natural stimuli not correlated with the VE; and exceeding response thresholds in the modality used for the substitution. These observations lead to the following hypothesis.

Hypothesis: Visual and auditory cues for acceleration and velocity substituting for absent multimodal sensory stimulation and action capabilities information can enable the realization of the catchability affordance in VEs, as confirmed by testing for the 1:1.2 ratio of actually catchable balls to those perceived catchable.

It is not evident what form these visual and auditory cues should take. Specifically, it is not known how extensive the cue would have to be, in terms of sensory system thresholds. For example, if the visual cue is a representation of body lean, it is not known whether the cue has to be a realistic representation of a body form, or a simple cross bar on a stick. Likewise, it is not known how intensive auditory cues would have to be to realize correct temporal perception. These open questions raise the need to identify which visual and auditory cues for locomotion provide the most effective substitution for realization of passability.

Hypothesis: An appropriate minimal form for visual and auditory cues of locomotion can be found, as confirmed by measuring threshold responses to a variety of cues.

Realization of Flyability

Flyability is not an action capability of humans in the natural environment, but its inclusion in the VEPAB indicates it is frequently provided as a capability in virtual environments (Lampton et al., 1994). Since flyability is not a natural action capability, there are no studies that suggest geometric or kinematic relationships on which flyability would depend. In fact, realization of flyability would only arise when a specific set of environmental effectors related to this capability is specified, and when experimentation leads to an understanding of this action capability (Gibson & Pick, 2000). Recall that Gibson et al. (1987) showed that the transversability of different surfaces depended, for infants, on the mode of locomotion (crawling or walking), and that the pattern of experimentation to learn what a surface afforded differed between crawlers and walkers. New VE users are comparable to infants, except that they come to the virtual world with a wealth of possibly misleading experience. Of course, since VEs are not required to conform to the laws of physics, no specific environmental effectors are required to enable users to fly in a virtual environment. Users would become aware of the possibility of flying, just as babies become aware of the possibilities of

crawling and walking, through a process of experimentation with their environment effectors based on sensory stimulation, leading to experience that such locomotion modes are possible.

Once a VE user is aware that flying is possible, then the realization of the flyability affordance is much the same as realizing the affordance of any other form of locomotion such as crawling, walking, or running. That is, its realization will involve the integration of some combination of environmental and self-stimuli in the context of some goal or motivation. Thus the stimulus integration mechanism can be seen as finding the best-fit mode within the constraints of the environment while realizing a locomotion affordance. Gibson et al. (1987) noted that the environment specifies information about space available and the surface that the human uses in realizing the affordance of various forms of locomotion. For example, Warren (1984), in his study of stair climbing, determined that the critical ratio of leg length to stair height, the point at which subjects shifted from normal stair stepping to crawling, was also the point at which shifting locomotion modes became more efficient in terms of energy expected. Kelso (1995) provides an in depth consideration of how energy consumption relates to locomotion mode chosen.

Since flyability is not an affordance of the natural environment, it is obvious that VEs do not intrinsically enable the realization of this affordance. This failure is a direct result of impoverished, absent, or conflicted cues that relate to the flying action capability in VEs as shown in Figure 5. Enabling realization of flyability would involve providing sensory substitution stimuli about specific environmental effectors and body stature properties, which combine to create the action capability of flying. Such stimulation integration would depend on seven key sources of information in order to realize the flyability affordance. First, goals or motivations to fly must exist. In the VEPAB documented in Lampton et al. (1994), windows and elevators enabling level changes create this motivation. Next, sensory stimulation in an environment must provide information about the space available. Next, sensory stimulation about the user must provide information about the spatial

requirements of the specified flying action capability. For example, if wings are the environmental effectors that relate to flying action capability, then there must be sufficient space to extend and flap the wings. The stimulus integration mechanism would arrive at the percept of the flyability affordance by scaling space availability to the space required for flying action in the context of a motivation to fly. The realization of the flyability affordance can be detected by observing the decision made by a subject when presented with the choice to walk or fly toward a goal. Table 7 summarizes the sources of information required to realize flyability.

Table 7: Information required for the realization of flyability.

Required information	Enabling information in a virtual environment
Desire to fly	Internal state information which includes goals, motivation
Spatial constraints of room	Visual
Spatial requirements for flying	Impoverished, absent, and/or conflicted in a VE

As was the case for passability and catchability, impoverished, absent, or conflicted information needed to realize the affordance of flyability in a VE might be provided by a sensory substitution scheme. To be effective, the substitution would have to replace missing exterocepters (i.e., visual, auditory cues), interceptors (i.e., kinesthetic, vestibular cues), and propriocepters (i.e., cutaneous cues) associated with accelerating to flying, as well as overwhelm any conflicting cues from the natural environment. Due to visual dominance (Storms, 2002), and the strong association between spatial perception and visual stimuli (Shimojo & Shams, 2001), visual cues for action capabilities may be able to substitute for absent multimodal sensory stimulation and action capability information, thereby enabling the realization of the flyability affordance in virtual environments.

54

Visual cues representing space requirements of the environmental effectors for flying may dominate other sensory stimulation, such as kinesthetic and vestibular cues about self-acceleration in the nature environment, by exploiting the visual dominance effect. In addition to visual dominance, as aforementioned, many researchers (Shimojo & Shams, 2001; Popescu et al., 2002) have noted the strong association between visual stimuli and spatial perception. Since flyability is a spatial perception, visual cues could exploit this strong correlation.

In terms of the realization process described for flyability, visual cues in a VE would provide impoverished, absent or conflicted information about flying action capability in the virtual environment. Armed with this additional information, a user's stimulus integration mechanism would arrive at the percept of the flyability affordance by scaling information about space available constraints to the space required for flying, when motivated by the goal to fly. Thus, visual cues, for the specific affordance of flyability, may be able to meet the previously described requirements for a successful sensory substitution scheme: replacing sensory modalities not represented in a VE by exploiting the visual dominance effect, outweighing natural stimuli not correlated with the VE; and exceeding response thresholds in the modality used for the substitution. These observations lead to the following hypothesis.

Hypothesis: Visual cues for space required to fly substituting for absent multimodal sensory stimulation and action capabilities information can enable the realization of the flyability affordance in VEs, as demonstrated by users choice of flying when presented with multiple, valid forms of locomotion.

It is not evident what form these visual cues should take. First, the cues should relate to the environment effectors that enable flying capability. Further, it is not known how extensive the cue would have to be, in terms of visual thresholds. For example, if the visual cue is a representation of

body size, it is not known whether the cue has to be a realistic representation of a body form, or a simple rectangle. These open questions raise the need to identify which visual and auditory cues for locomotion provide the most effective substitution for realization of flyability.

Hypothesis: An appropriate minimal form for visual cues for flying can be found, as confirmed by measuring threshold responses to a variety of cues.

Chapter 3 provides details of the proposed method by which the present research will test the stated hypotheses.

CHAPTER 3: METHOD

The method used to evaluate the hypotheses is an experimental program. The following

discussion defines the participant population, apparatus, tasks, procedure, VE, and experimental

design used in the experimental program.

Participants

Participants for the experiments were Boeing company employees (54 males, 15 females). All

participants completed a demographic survey, the results of which are summarized in Table 8. The

number of responses does not always sum to the same total because some participants chose not to

respond to particular questions.

Table 8: Demographics of participants.

Factor	Response					
Age	Average	41.71	Std Dev	10.41		
Gender	Female	15	Male	54		
Height (inches)	Average	69.80	Std Dev	3.73		
Color Blind	No	66	Yes	3		
TV Signals Problem	No	69	Yes	0		
Normal Vision	No	44	Yes	25		
Vision Correction	No	3	Yes	41	N/R	25
Using Now	No	11	Yes	36	N/R	22
Unusual Vision	No	36	Yes	6	N/R	27
Normal Hearing	No	8	Yes	61		
Hearing corrected	No	5	Yes	3	N/R	61
Wearing correction	No	5	Yes	2	N/R	62
Unusual hearing	No	15	Yes	2	N/R	51
Handed	Right	56	Left	10	Ambidextrous	3

N/R = No Response

Participants were randomly assigned to one of a number of different groups, which determined their treatment as defined in the experiment design.

The first participant group was the *Preliminary* group, which participated in pilot studies. The Preliminary group included ten participants, and their results were encoded as P-xxx-[H | S], where "P" indicates Preliminary, "xxx" ranged from 001 to 010, and "H | S" indicates the VE was presented via a HMD or "S" if the VE was presented via a Computer Projection Screen.

The second participant group was the *Baseline* group, which served as a control group experiencing none of the cues designed to enable the perception of the affordances. The Baseline group included five participants, and their results were encoded as B-xxx-[H | S], where "B" indicates Baseline and "xxx" is a number from 001-005, and "H | S" is as for the Preliminary group. The control group experienced changes in the room configurations (e.g., different passageway widths) but were not provided with any cueing. The results from this group re-establish what is already known about affordances in VEs -- they are not perceived as they are in the real world.

The third participant group was the *Final* group, which experienced the formal treatment as discussed in the experiment design. The Final group included 43 participants, and their results were encoded as Fxxx-[H | S], where "xxx" is a number from 001 to 043, and "H | S" is as for the Preliminary group. This group was divided into two subgroups because of complications with the "thud" cue, which was judged to be unsatisfactory and thus was changed after F020. This was the only change between the F001-020 and F021-043 groups.

The fourth participant group was the *Header* group. The Header group included three participants, and their results were encoded as Hxxx-H, where "xxx" is a number from 001-005. This group was only run with the HMD. Observing the participants' decisions to fly or not led to

insights into the perception of this affordance. The original window that participants could fly through had no "top" or header (i.e., the window was not constrained in four directions as was the doorway), the presence of which could have diminished its ability to afford flying. The VE was thus modified to include a "header" on each wall, and an additional participant group was run with this configuration.

The fifth participant group was the *Alternate* group. The Alternate group included five participants, and their results were encoded as Axxx-H, where "xxx" is a number from 001-005. This group was only run with the HMD. Although the order of configuration was randomly selected, to confirm that the particular order of room configurations (see Figure 8) was not incidentally a fortunate one particularly conducive to realizing affordances, an "alternate" group was run with a different randomly selected room configuration.

Five participants began and were unable to complete the experiment. For the most part, they became too ill to continue. One participant played with the apparatus, crashed the environment, and declined to complete the experiment. The participants that did not complete the experiment were encoded as Xxxx-[H | S], where "xxx" is a number from 001-005, and "H | S" is as for the Preliminary group. Upon starting analysis, the results files for participant F039 were found to be corrupted, so F039 was not considered in the analysis. Finally, one participant had a profound loss of hearing, and this result was separately encoded as I001.

Apparatus

All of the experiments utilized the same apparatus. A VE was implemented in a Renderware engine running on PC in Windows 2000. The engine is capable of simulating collision detection, networking, avatars, and some special effects. Graphics models were constructed in 3D Studio Max, and exported in Renderware's format. Visual and audio information were presented in one of two

modes: either a Virtual Research V6tm HMD or a Sharp NV2U Computer Projector. The resolution of the HMD was 640 x 480 pixels spread over two eye point displays; the resolution of the projector was 800 x 600 pixels. For both presentation modes, the participants were positioned 8 feet from the projection screen in a nonadjustable height chair at a desk 30" high off the ground with no obstacles within their reach. The participants were asked to line up their chairs on a piece of masking tape marking the center line of the project screen. Users controlled their movements throughout the VE with an optical computer mouse.

Three questionnaires were used in this experiment.

1) Immersive Tendencies Questionnaire: a 34 question survey, with each question answered along a seven point scale, which indicates how likely the respondent is to immerse (or "lose") themselves in an artificial experience (see Witmer & Singer, 1996)

2) Motion History Questionnaire: a 20 question survey, with multiple response formats, that creates a record of the respondent's experience with various kinds of artificial motion and motion sickness (see Kennedy & McCauley, 1984)

3) Simulator Sickness Questionnaire (SSQ): a 27 question survey, with each question answered along a four point scale from "none" to "severe", which creates a measure of the respondent's present physical well-being (see Kennedy Lane, Berbaum, & Lilienthal, 1993).

Tasks

Participants conducted activities in a VE that required walking through passageways, running to catch an object, and flying. These tasks were incorporated into a game-based theme to maintain participant interest. The tasks involved traversing a series of virtual rooms, which exhibited varying perceptual stimuli (i.e., each room was configured per the experimental design discussed below). In

60

each room, the participant was asked to approach an orientation post in order to orient within the room and then exit the room as appropriate for the experiment configured in it. The orientation post was located fifteen meters from and centered on the exit wall in each room. Successful orientation by the participant triggered the post to sink into the ground during which the participant's position was frozen. After sinking, the post was positioned to the next room to assist in orienting the participant during the next task.

For the passability task, participants were instructed that if the room had a single exit, then they should first trigger the orientation post and then exit the room's passageway in the most comfortable way, i.e., rotate if that made it easier to exit the room. The VE measured the participant's actual behavior in order to assess passability (i.e., rotation angle).

For the catchability task, participants were instructed that if a room had two passageway exits and a cannon on the floor, the participant should first trigger the orientation post and then observe a virtual ball shot from the cannon and judge whether the ball was catchable or not. Participants were told that movement might improve their judgment. The virtual cannon was located on the far wall across from the entrance in direct line with the orientation post. Once the ball was shot, the participant was to judge whether they could have caught the ball in the air from their location when the ball was shot. The balls were shot with velocities that led to their impact on the floor within about two (uncatchable) to three (catchable) seconds. Upon impact, the balls bounced off the floor. The ball was shot as either uncatchable (landing more than > 1.2 times the participant's range) or catchable (landing <=1.2 times the participants range) as defined by the experimental condition; the values being chosen for consistency with Oudejans et al. (1987). Catchable balls had greater initial speeds and achieved a greater height than uncatchable balls. Participants were instructed to record their catchability judgment by exiting out of one of the two passageways leaving the room, either the left passageway (also marked by a green block) if the ball was catchable in the air, or the right

passageway (also marked by a red block) if it was not. The VE measured the participant's actual behavior in regards to catchability (i.e., which door they exited).

For the flyability task, participants were instructed that if the room had a passageway and a window, then they should first trigger the orientation post and then exit either room's passageway or window in the most comfortable way (i.e., fly if that is easier). The VE measured the participant's actual behavior in regards to flyability by recording the altitude above floor level (or 'ground") at which they exited the room. A more detailed explanation of the tasks is in the protocol contained in Appendix A.

Virtual Environment

The following discussion explains the representation in the VE experienced by the participants. In order to address the validity issues discussed, and to make the gathering of the experimental data as efficient as possible, the experimental program occurred in a single integrated virtual experience.

The virtual world modeled was similar to the interior of the University of Central Florida Engineering II building with regard to walls. The ceiling was modeled as a cloudy sky, so that participants could fly without concern for colliding with the ceiling. The result was an outdoor maze-like structure. Each participant's original position in the virtual world was within a large room used to orient them to the controls. Figure 7 illustrates the initial position of each participant within the virtual environment.
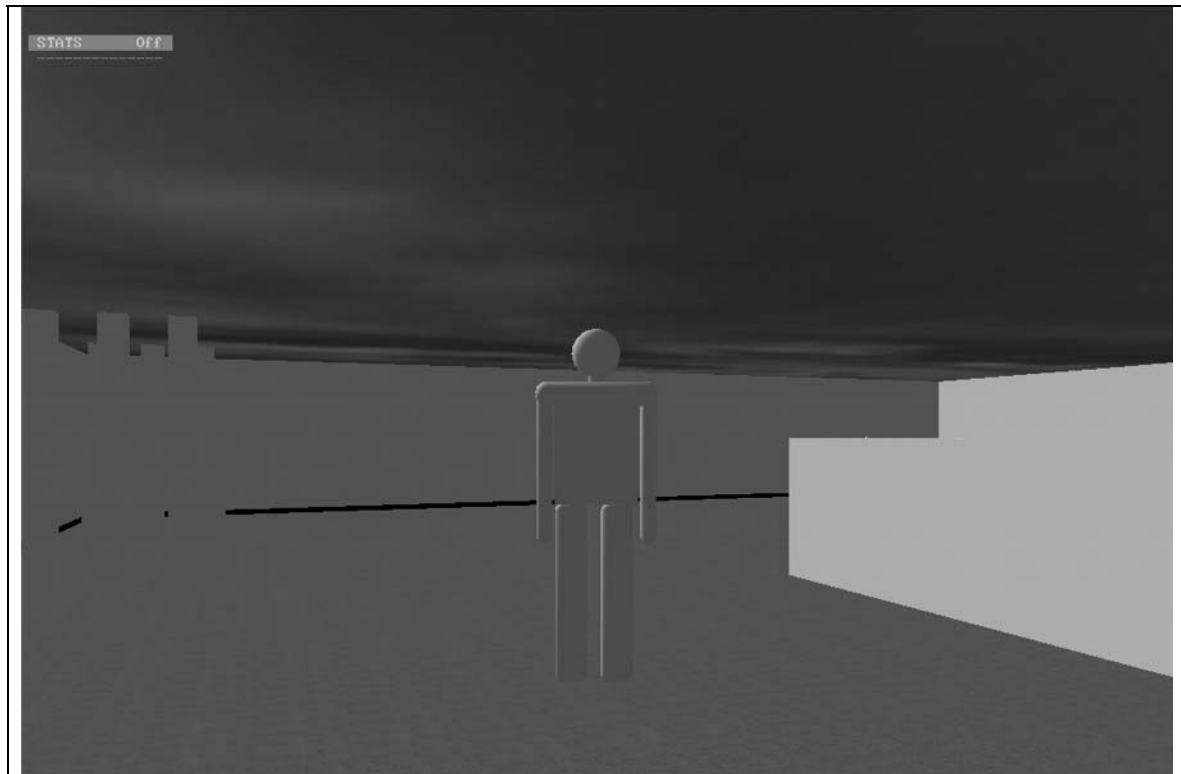
Figure 7: Participants' initial position within the virtual environment.

The qualities of the cues in this environment are of concern as the sophistication of the various visual and audio cues may be an unblocked source confounded with the dependent variables. Surdick, Davis, King, and Hodges (1997) studied the impact of seven different visual cues (brightness, relative size, relative height, linear perspective, foreshortening, texture gradient, and stereopsis) on the perception of distance in virtual environments. They found that foreshortening, linear perspective, and texture gradient were sufficient for perception of the distance of geometric objects. The VE used as the experimental apparatus therefore included high quality representations of these so-called ground intercept cues and comparatively low quality representations of the other cues. Foreshortening and linear perspective were fully enabled in the virtual environment. Strong texture differentials between the walls and floors were employed (i.e., walls appeared as "flat paint"

whereas floors were a patterned carpet). Brightness was accounted for as a single directional light source, which provided minimal contrast. The size and height of objects in the VE were correct in relation to one another but many small details, such as light switches, were omitted. The VE was not stereoscopic; the same image was presented to each eye within the HMD.

There were 26 separate rooms in the VE, including the orientation room, 24 task rooms in which the experimental conditions were presented, and a completion room. The orientation and the completion rooms were represented as 25 by 25 meters. Each of the task rooms were represented as five meters wide by 20 meters long. The rooms were arranged in a serpentine fashion to prevent the participant from seeing the configuration of the next room through the exits to the current room. The participant's initial position was in the orientation room in which the participant was directed through a series of familiarization tasks. When ready, the participant exited the orientation room and progressed through the task rooms. To assist the participant in continuing correct progress through the rooms, an orientation cue (represented as a triangular post) was presented at the entrance to every room. When participants entered a room correctly positioned, the cue sunk into the ground, and emerged in the next room. After progressing through all of the task rooms, the participant emerged into a large completion room and the VE was terminated. Figure 8 shows the layout of the rooms in the VE, from the orientation room, through the 24 task rooms, to the completion room. Figures 9 through 11 are examples of passability, catchability, and flyability rooms, in turn.
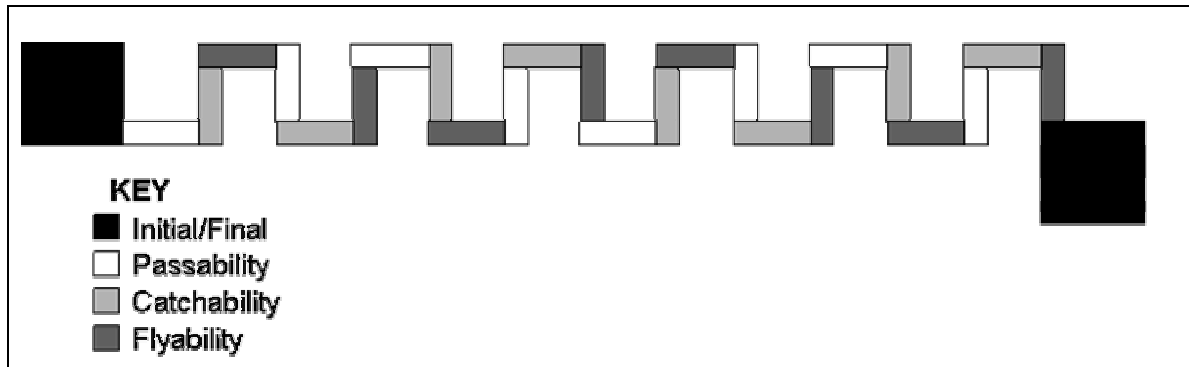
Figure 8: Layout of the virtual environment.
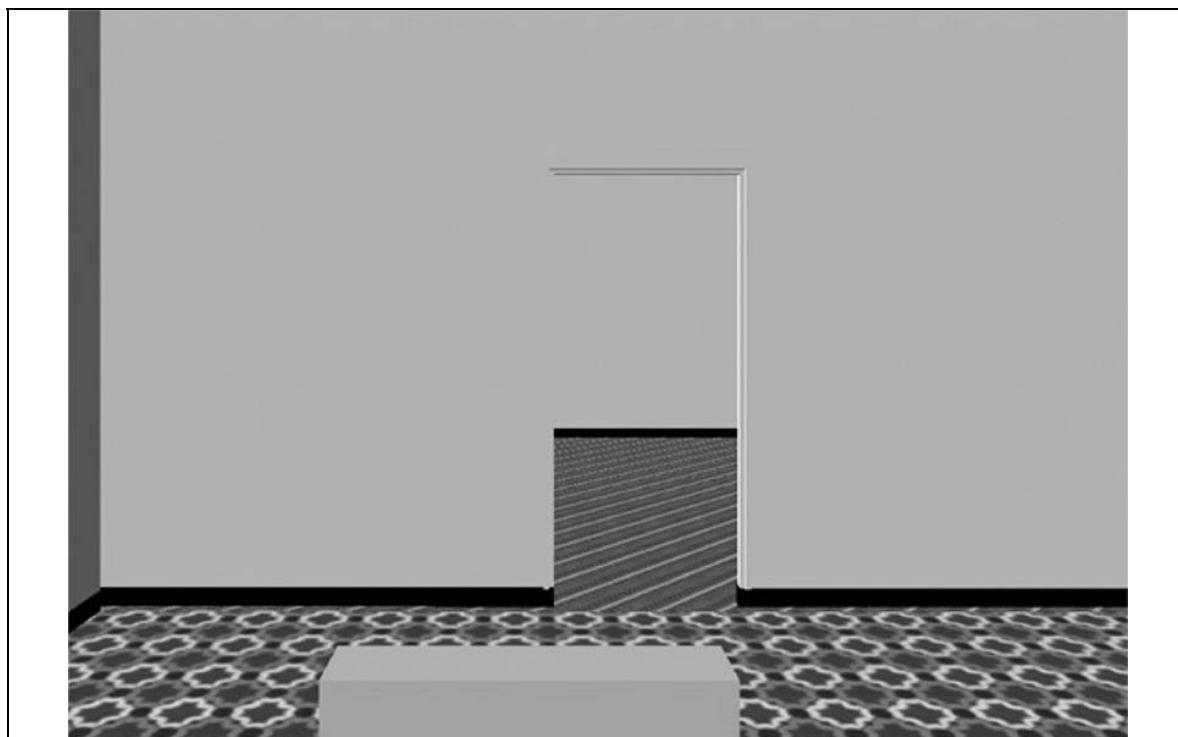
Figure 9: Example of a passability room.
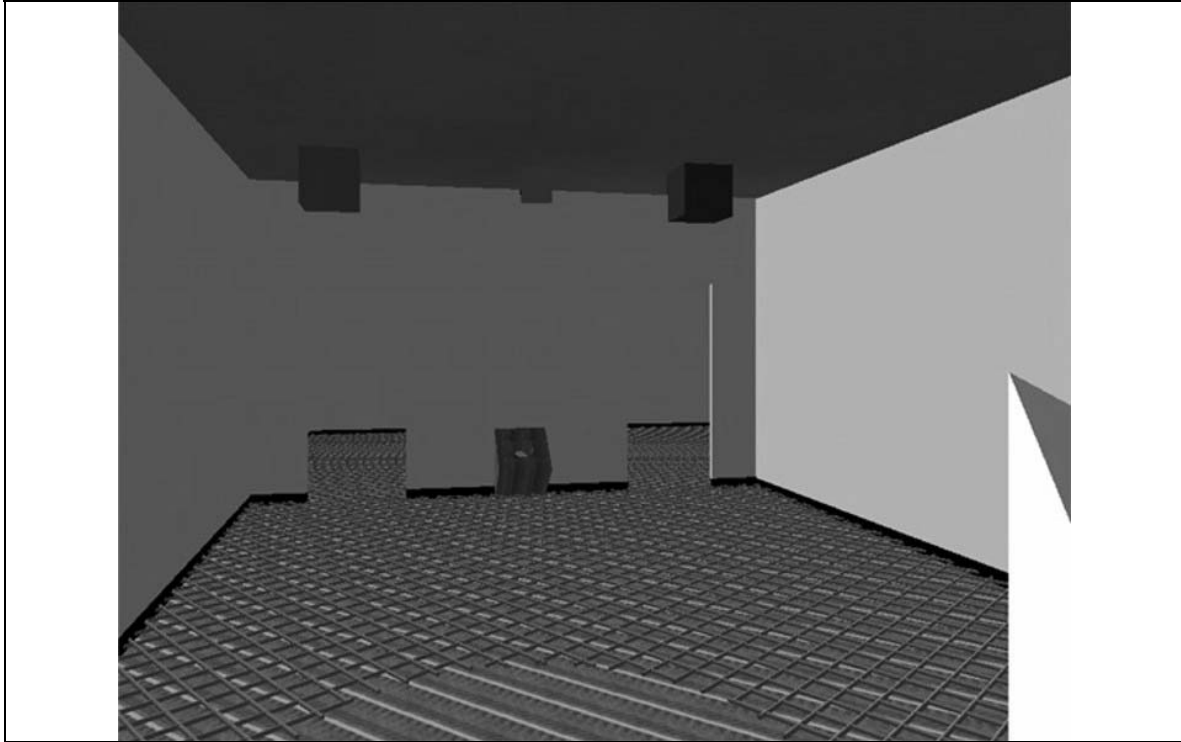
Figure 10: Example of a catchability room.
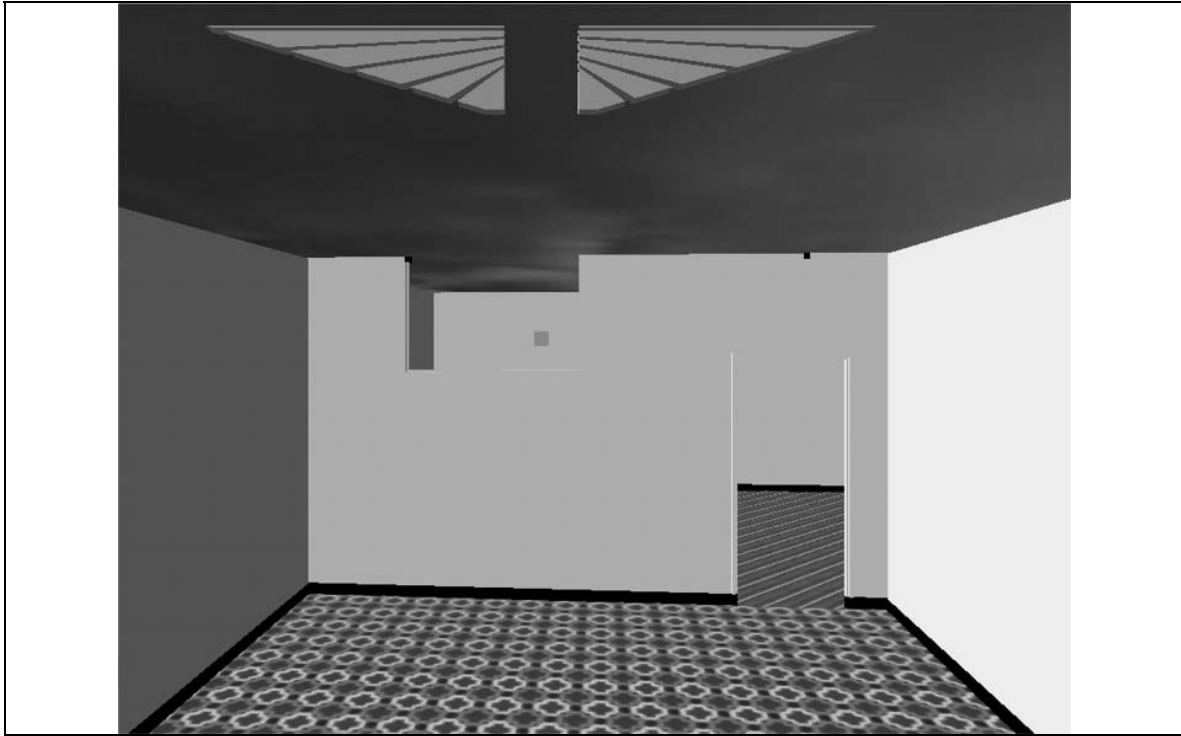
Figure 11: Example of a flyability room.

Procedure

Appendix A contains the protocol for the experiment as summarized in the following discussion. The protocol was defined by a script for the experimenter to use in briefing each participant and exercising the apparatus. The general procedure was as follows:

1) Informed Consent

2) Pre-questionnaires (demographics, etc.)

3) Briefing on environment

4) Entry into environment

5) For each task:

- Briefing on objective

- Observe behavior

- Performance measurement

- Post-questionnaires

- Results recorded

First, all participants were briefed and asked to make an informed consent to the experiment. No participants declined to participate at this point. After indicating their informed consent, participants completed a demographics form, an Immersive Tendencies Questionnaire (Witmer & Singer, 1996), and Motion History Questionnaire (Kennedy & McCauley, 1984). Prior to exposure to the VE, each participant completed the Simulator Sickness Questionnaire (SSQ) to baseline their well-being prior to exposure (Kennedy et al., 1993). In order to proceed with the experiment, each

participant's pre-SSQ score had to fall below 7.48, which qualified the participant to be in good health for the experiment.

Each participant was randomly assigned to one of the treatment conditions as discussed in the section following. The experimenter briefed each participant on the use of controls for movement, rotation, and flight in the VE as defined in Appendix A. The experimenter encouraged each participant to become comfortable with these controls in the orientation room by maneuvering around obstacles placed in the room. The experimenter instructed each participant to exit the orientation room when comfortable with the controls through the only passageway in the orientation room.

During exposure, participants maintained a seated position while wearing an HMD and traversing through the VE completing the tasks described above. The exposure time for each treatment was approximately 30 minutes. Immediately following each exposure period, post-SSQ measures were obtained. If the participant's score exceeded the threshold value of 7.48, the experimenter terminated the experiment. If the experimenter terminated the experiment, the experimenter encouraged the participant to follow a recovery protocol until their SSQ score fell below the threshold.

Experimental Design

The experimental design consisted of a series of experiments, each of which tested the hypotheses in a range of conditions. The experimental space was required to address six hypotheses and the dependent variables implied by those hypotheses. The related independent variables that affected the dependent variables were numerous. The experimental design therefore adopted the sequential experimentation approach recommended by Han, Williges, and Williges (1997). The experimental design adopted three main parts of the sequential experimentation approach:

1) Screening Studies: The experimental program conducted pilot studies to screen for the appropriate levels for each factor based on qualitative and quantitative information collected. Preliminary experimental runs provided qualitative and quantitative information to assess the level of the cues presented, which were adjusted for the final experimental runs.

2) Division of the independent variable into subsets: The experimental program divided independent variables into subsets, one subset for each of the three affordances under consideration. The result of this was to reduce the experimental space from twenty-four independent variables (requiring 128 run configurations for a resolution IV design) to three subsets of four independent variables (requiring 24 run configurations for a resolution IV design).

3) Sufficient resolution: The experimental design left main effects and two way interactions un-confounded.

The independent variables for each subset may be further divided into two classes: those providing evoking circumstances and those providing substitutionary cues for physical characteristics which may enable the realization of a given affordance. The evoking circumstances test the properties of objects within the environment under levels that should lead to the realization of an affordance and levels which should not. The following discussion explains the evoking circumstances for each affordance (passability, catchability, and flyability), and the form of the substitutionary cues for physical characteristics and object properties considered.

Passability Experiment

The theoretical discussion developed a hypothesis that a VE could enable the realization of the passability affordance by providing cues as to the participant's body characteristics substituting for missing, impoverished, and conflicted kinesthetic and vestibular sensory stimuli. A successful

substitution scheme enabling the realization of passability should result in the average VE user matching the 1:1.3 shoulder width to passage width ratio for comfortable passage found in Warren and Whang's (1987) study. Stappers (1999) found that this affordance is not realized in VEs as it is in realty. It was not known in advance what substitution stimuli would be most effective, thus a hypothesis secondary to the first, was developed that appropriate cues for body stature could be found. Table 9 shows the physical characteristic cues that the passability experiment investigated. In the experimental conditions in which these cues were active, participants saw these cues during their entire time in the task room.

Table 9: Substitutionary cues for physical characteristics possibly enabling passability.

Passability cues	Form of the Cue	Cue Behavior	Motivation
Bar	- Horizontal rectangular block (see Figure 9) - Width defined by virtual shoulder width - Superimposed on an egocentric view (across bottom)	- Match position and heading to virtual body's when mouse moved - Rotate around vertical axis when virtual body rotated by depressing left mouse button	Minimal stimuli about shoulder width
Form	- Simplified head, neck, and shoulders - Width defined by virtual shoulder width - Superimposed on an egocentric view (across bottom)	- Match position and heading to virtual body's when mouse moved - Rotate around vertical axis when virtual body rotated by depressing left mouse button	More than minimal stimuli about shoulder width
Peripheral	- Gap in cross-hatched mesh in plane parallel with the walls - Gap width defined by virtual shoulder width - Superimposed on a egocentric view (top to bottom)	Match position and heading to virtual body's when mouse moved	Maximum stimuli about shoulder width

The passability experiment required participants to choose whether or not to rotate their virtual body so as to facilitate their exit. The task rooms for the passability experiment had a single exit, a passageway of varying widths from room to room. Passability is evoked in circumstances where an observer perceives the passageway as being narrow, and is not evoked when the observer perceives the passageway to be wide. The passability experiment therefore includes an independent variable for the actual width of the passageway as an evoking circumstance. If the substitutionary cues for physical characteristics possibly enabling passability are effective, then most participants should rotate when presented with narrow passageways, and few should when presented with wide passageways. Based on the data found in Warren and Whang (1987) and Stappers (1999), the experimental design assigned 80% as the predicted value for 'most' rotating, and 20% as the predicted value for 'few' rotating.

Table 10 shows the independent variables for the passability experiment, which included the presence or absence of each cue, in addition to passageway width. The levels considered for the evoking circumstance of passability, namely passageway width, bracket the 1:1.3 ratio (i.e., levels of 1 and 1.5 times the shoulder width) at which passability has been shown to be afforded, which should result in a measurable effect. The dependent variable measured in the VE was degree of body rotation, which indicated whether passability had been realized or not.

Table 10: Independent variables for the passability experiment.

Variable	Level (-)	Level (+)
Bar cue	Absent	Present
Form cue	Absent	Present
Peripheral cue	Absent	Present
Passage width	1.0 x user's shoulders	1.5 x user's shoulders

Catchability Experiment

The theoretical discussion developed a hypothesis that a VE could enable the realization of the catchability affordance by providing cues as to the participant's action capabilities. A successful substitution scheme enabling the realization of catchability should result in the average VE user matching the catchability judgments values found in Oudejans et al. (1996), specifically the 1:1.2 ratio of actually catchable balls to those perceived catchable. This cue would provide information substituting for missing, impoverished, and conflicted kinesthetic and vestibular sensory stimuli. It was not known in advance what substitution stimuli would be most effective, thus a hypothesis secondary to the first was developed that appropriate cues for self-acceleration and range could be found. For example, it was possible that either visual or auditory stimuli would be sufficient, so the experiment had to be able to analyze the separate contributing effects of each stimulus. Table 11 shows the physical characteristic cues of self-acceleration and range cues that the catchability experiment investigated. In the experimental conditions in which these cues were active, participants heard or saw these cues upon entering the room and approaching the orientation post, as well as if movements were made after the cannon ball was shot.

Table 11: Substitutionary cues for physical characteristics possibly enabling catchability.

Catchability cue	Form of the Cue	Cue Behavior	Motivation
Stick	• Vertical rectangular block • Height defined by virtual shoulder width • Superimposed on an egocentric view (centered, low)	• Match position and heading to virtual body's changes when mouse moved • Rotate around horizontal axis away from the user as speed increased	• Minimal visual stimuli about self-acceleration and velocity
Thud	• Auditory "beeps" • Separation distance between beeps indicated speed	• Separation distance between beeps inversely and exponentially related to speed	• Audio stimuli about self-acceleration and velocity
Periphery	• Cross-hatched mesh plane parallel with the floor (see Figure 10) • Circular gap width defined by reach range at current location • Superimposed on a egocentric view (slightly off the floor)	• Match position and heading to virtual body's changes when mouse moved	• Maximum visual Stimuli about self-acceleration and velocity

The catchability experiment required participants to judge whether or not a ball was catchable, that is, whether or not they could maneuver so as to intercept the ball in the air. The task rooms for the catchability experiment contained two exits (a left and right door), and a cannon. After the participant successfully approached the orientation post, a ball was fired from the cannon. Catchability is evoked in circumstances where an observer perceives an object (e.g., a ball) to be within their reach range, and is not evoked when the observer perceives the object to be outside of their reach range. The catchability experiment therefore includes an independent variable for the

shot range of the ball as an evoking circumstance. If the substitutionary cues for physical

characteristics enabling catchability are effective, then most participants should judge the ball

catchable when presented with a ball shot in range, and few should when presented with a ball shot

out of range. Based on the data found in Oudejans et al. (1996), the experimental design assigned

80% as the predicted value for 'most' correctly judging catchability, and 20% as the predicted value

for 'few' correctly judging catchability.

Table 12 shows the independent variables for the catchability experiment, which included the

presence or absence of each cue considered, as well as the shot range (i.e., uncatchable versus

catchable). The levels considered for the evoking circumstance of catchability, namely shot range,

bracket the 1:1.2 ratio at which catchability has been shown to be afforded, which should result in a

measurable effect. Specifically, balls shot in range fall within reach of the participant's range ($<=1.2$)

from the time of shot, and balls shot out of range fall outside of a circle whose radius is 1.5 times

the range of the participant from the time of the shot. The dependent variable was body position

relative to the exit passageway location in meters, which indicated whether catchability had been

realized or not. Exiting the left passageway indicated the participant believed the ball to be catchable,

whereas exiting the right meant that the participant judged it not to be catchable.

Table 12: Independent variables for the catchability experiment.

Variable	Level (-)	Level (+)
Stick cue	Absent	Present
Thud cue	Absent	Present
Peripheral cue	Absent	Present
Shot range	Out of range	In range

Flyability Experiment

The theoretical discussion developed a hypothesis that a VE could enable the realization of the flyability affordance by providing cues as to a user's body size, substituting for missing, impoverished, and conflicted kinesthetic and vestibular sensory stimuli. A successful substitution scheme enabling the realization of flyability should result in the average VE user choosing to fly. It was not known in advance what substitution stimuli would be most effective, thus a hypothesis secondary to the first was developed that appropriate cues for body size could be found. Therefore, the flyability experiment presented a range of substitution stimuli that might be appropriate for body size. Table 13 shows the physical characteristic cues that the flyability experiment investigated. In the experimental conditions in which these cues were active, participants saw these cues during their entire time in the task room.

Table 13: Substitutionary cues for physical characteristics possibly enabling flyability.

Flyability cue	Form of the Cue	Cue Behavior	Motivation
Wings	• Stylized wing (see Figure 11) • Gap width defined by virtual shoulder width • Superimposed on an egocentric view (across top)	• Match position and heading to virtual body's changes when mouse moved • Rotate around vertical axis when virtual body rotated by depressing left mouse button	• Minimum stimuli about body width and height
Periphery	• Gap in cross-hatched mesh in plane parallel with the walls • Gap width defined by virtual shoulder width and body height • Superimposed on a egocentric view (top to bottom)	• Match position and heading to virtual body's changes when mouse moved	• Maximum stimuli about shoulder width and body height

The flyability experiment required users to choose between two forms of locomotion, namely flying or walking. The task rooms for the flyability experiment included two exits: one a ground level doorway to the side of the straight-ahead path, and one a window directly in front of the user. Flyability is not an affordance present in reality; therefore its evoking circumstances are unknown. The experimental design includes two independent variables that may be evoking circumstances for flyability: window height and window width. As in passability and catchability, the supposition is that flyability will be evoked when observers perceive that flying is possible and easier than other choices. The supposition is that participants would be more likely to fly over low, wide windows, and less likely to flow over high, narrow windows. If the substitutionary cues for physical characteristics possibly enabling flyability are effective, then most participants should chose to fly when presented with low, wide windows, few should choose to fly when presented with high, narrow windows, and some should choose to fly in the intermediate conditions (high-wide or low-narrow). To maintain consistency with the other affordances, the experimental design assigned 80% as the predicted value for 'most' flying and 20% as the predicted value for 'few' flying; while adding a third condition of 50% for 'some' flying.

Table 14 shows the independent variables for the flyability experiment, which included the flyability cues, as well as the height of the window off the ground. There could have been effects that confound the realization of flyability, such as the size of the aperture (window) to fly through, so the flyability experiment included window width as a blocking variable. The lower values in Table 14 match experiences users have in the real world for climbing through a window using a ladder (Warren, 1984). The higher values were chosen to create a likelihood of seeing an effect, namely that users would choose to fly. Finally, the dependent variable was altitude above the floor as measured in meters, which indicated whether flyability had been realized, or not.

Table 14: Independent variables for the flyability experiment.

Variable	Level (-)	Level (+)
Wings Cue	Present	Absent
Peripheral Cue	Present	Absent
Height of window	1.0 meters	2 meters
Width of Window	1.5 meters	2 meters

The passability, catchability, and flyability experiments presented two levels of five factors, resulting in 2^4 (i.e., 16) different cases. Since the purpose of these experiments was to discover main effects, and resources are a constraint on any experiment, these experiments were conducted as a 2_{IV}^{4-1} fractional factorial design, as illustrated in Table 15. This is a resolution IV design, in which main effects were confounded with three way interactions, as recommended in Han, Williges, and Williges (1997).

Table 15: Standard 2_{IV}^{4-1} fractional factorial design.

Case	A	B	C	D=ABC
1	-	-	-	-
2	+	-	-	+
3	-	+	-	+
4	+	+	-	-
5	-	-	+	+
6	+	-	+	-
7	-	+	+	-
8	+	+	+	+

Table 16 shows the overall experimental design in standard order for the factors for each affordance. The factors are the various substitutionary cues and evoking circumstances that should lead to the perception of the affordance; the combination of which define a configuration. The design required eight configurations for each affordance (as opposed to sixteen configurations in the full factorial design). There were three affordances considered, so there was a total of 3x8 or 24 configurations to run. The configurations were presented to the participant in a series of virtual "rooms," with one configuration per room. Per standard experimental procedure, the configurations were presented in a random order, with a passability room always preceding a catchability room, which in turn always preceding a flyability room. More specifically, in order to block undesirable learning effects, the rooms were configured in random order, except that the selection ensured a rotation between passability, catchability, and flyability configurations. For example, a catchability or flyability room always succeeded a passability room, never another passability room. Therefore, the order within each class of rooms was randomly selected. An arbitrary 24 different random selections was made to select the presentation order of the experimental conditions. Each participant constitutes a replication of the 24 conditions, except that participants in the Baseline group experienced only the evoking circumstances and those in the alternative group experienced the rooms in a different order.

Table 16: Overall experimental design.

Treatment Condition	Affordance Cue				Presentation Order
Passability	Bar Cue	Form Cue	Peripheral Cue	Passage Width	
1	-	-	-	- (narrow)	7
2	+	-	-	+ (wide)	1
3	-	+	-	+	10
4	+	+	-	-	19
5	-	-	+	+	13
6	+	-	+	-	22
7	-	+	+	-	16
8	+	+	+	+	4
Catchability	Stick Cue	Thud Cue	Peripheral Cue	Shot Range	
9	-	-	-	- (catchable)	5
10	+	-	-	+ (not)	20
11	-	+	-	+	14
12	+	+	-	-	11
13	-	-	+	+	17
14	+	-	+	-	23
15	-	+	+	-	2
16	+	+	+	+	8
Flyability	Wings Cue	Peripheral Cue	Height of Window	Width of Window	
17	-	-	- (short)	- (narrow)	9
18	+	-	-	+ (wide)	6
19	-	+	-	+	21
20	+	+	-	-	15
21	-	-	+ (tall)	+	18
22	+	-	+	-	3
23	-	+	+	-	24
24	+	+	+	+	12

+ = cue present; - = cue absent (except were noted otherwise)

An additional issue is the possibility that the presentation media used might effect the

perception of an affordance. Therefore, the design included presentation media as an additional

"super factor" with two levels: HMD and computer projector on a screen. This was implemented

by repeating the configuration in Table 16 for each participant, alternating whether the HMD or the projector was first used.

In the complete experimental design each participant was exposed to all of the required configurations twice, once with the HMD and once with the Screen, thereby supporting analysis of effects within and between subjects for all of the factors.

<div align="center">

Experimental Validity

</div>

Weimer (1995) identifies two main ways in which the validity of an experimental program can be evaluated: internal and external validity.

<div align="center">

Internal Validity

</div>

Internal validity is the degree to which one can draw the conclusion that manipulation of the independent variables, and only that manipulation, has caused the observed change in the dependent variables. Internal validity, establishes that differences observed in the dependent variables are caused by changes in the independent variables, rather than simply correlated to those changes. There are a number of threats to internal validity, such as low statistical power, which means that true differences are not noted, and random heterogeneity, which means that differences noted are not true. These threats can be addressed by increasing the number of participants per group, and considering group differences (Gray & Salzman, 1998).   For the present research's experimental program, initial trials were used to predict the population variance, which in turn was used to select the number of samples required to resolve statistical tests to the standard 95% confidence level (Box, Hunter & Hunter, 1974). To address group differences, each participant was required to complete a form capturing their experience with VEs specifically and with HCIs in general.

Misuse of observation instrumentation is another threat to internal validity (Weimer, 1995). In this experimental program, the observation instrumentation was a time marked record of the results of the user's control inputs in terms of their position in the virtual environment.

Another threat to internal validity is a bias in the participant sample (Gray & Salzman, 1998). Participants were drawn from the Boeing Company's Huntsville work force. This group is roughly representative of the general population in many measures, but likely has more formal education than the populace at large. One strength of this sample group is that its age distribution is greater than a typical college environment.

A final threat to internal validity is unblocked variance in the experiment setting (Gray & Salzman, 1998). For the present research's experimental program, the setting was a standard laboratory and data collection occurred during normal business hours.

External Validity

External validity refers to the legitimacy of generalizing the results of the experiment to the population at large (Weimer, 1995). It is very difficult to get a true measure of the research's external validity. Threats to external validity include:

1) interaction between (pre)testing and the independent variables,

2) interaction between selection and the independent variables,

3) reactive effects of setting, and

4) multiple treatment interference.

Attempts were made to control these threats in the experimental design. For example, all participants received the same training period to learn the VE controls. The experimental setting

was designed to eliminate reactive effects, including placing the user in immersive and non-immersive settings. Finally, the experimental design blocks the effects of multiple treatments.

CHAPTER 4: RESULTS

The participant's responses to the Immersive Tendencies Questionnaire (Witmer & Singer, 1996), the Motion History Questionnaire (Kennedy & McCauley, 1984), and Simulator Sickness Questionnaire (Kennedy et al., 1993) resulting from the various surveys were analyzed by participant group, and found to demonstrate that there were no statistically significant differences between the groups. See Appendix B for this analysis.

<u>Pilot Study</u>

A pilot study was run to confirm that the experimental apparatus and design functioned appropriately. Table 17 shows issues discovered in preliminary runs and corrective actions taken. The results from the pilot study were thus used to revise the experimental apparatus and design, which were then used for the formal study.

Table 17: Issues discovered in the pilot study.

Issues	Corrective Actions
At the maximum altitude, users cannot see the window that they are trying to fly thru; effect is to increase difficulty of flying	Reduce maximum height such that users can see the window they fly through
"Negative Z" direction rooms have green and red backwards	Correct mislabeled catchability exits
Users remarked on cues they noticed, while not seeming to notice some cues this could be an interesting result	Add survey concerning "what cues did you notice?"
Current wings are wider than windows, which create a passability mis-affordance	Reduce wings width to between wide and narrow window width
Current bell sound for foot fall "thud" is linear, and the response does not change enough to help	Make foot thud an exponential curve
Various typographical errors and incorrect story line in briefing	Correct briefing
Short ball does not rise as high as long ball, making it easy to tell by eye if it's catchable	Make short ball's height match long ball's
Current columns are as high as the walls making the distance between them appear much smaller, which impedes training of passability	Reduce training columns height to match doorways
One passability room did not match experimental design	Correct passability encoding

Formal Study

The VE recorded each participant's behavior in the VE in a text formatted raw data file as show in Appendix C. The raw data consisted of room number, x position, y position, z position, rotation angle and speed for each video frame created. The VE ran at approximately 30 hertz, meaning that 30 frames were created every second of clock time. Neglecting aborted runs, the smallest resulting data file was 0.376 megabytes and the largest was 5.152 megabytes (P003-H) for a total of 238 megabytes of original data. The data collected consisted of more than 600,000 observations.

Analysis of Single Runs

The first analysis focused on analyzing single runs in terms of the raw data as related in the following discussion. The purpose of this analysis was to confirm that the VE was performing as expected; specifically that user behavior could be measured with raw data being collected (i.e., ensure data wasn't too noisy, needing transformation). Several single runs were subjected to this analysis. For the sake of space, the following discussion is constructed on a few random samples from the single runs.

Figure 12 plots a randomly selected participant's speed as a function of time in the virtual environment. It shows the participant accelerating and decelerating as they interact with the environment. Negative speed indicates that the participant was going backwards (i.e., this is actually velocity). Speed was not a dependent variable for any of the hypotheses, but provides confirmation of the VE's performance.
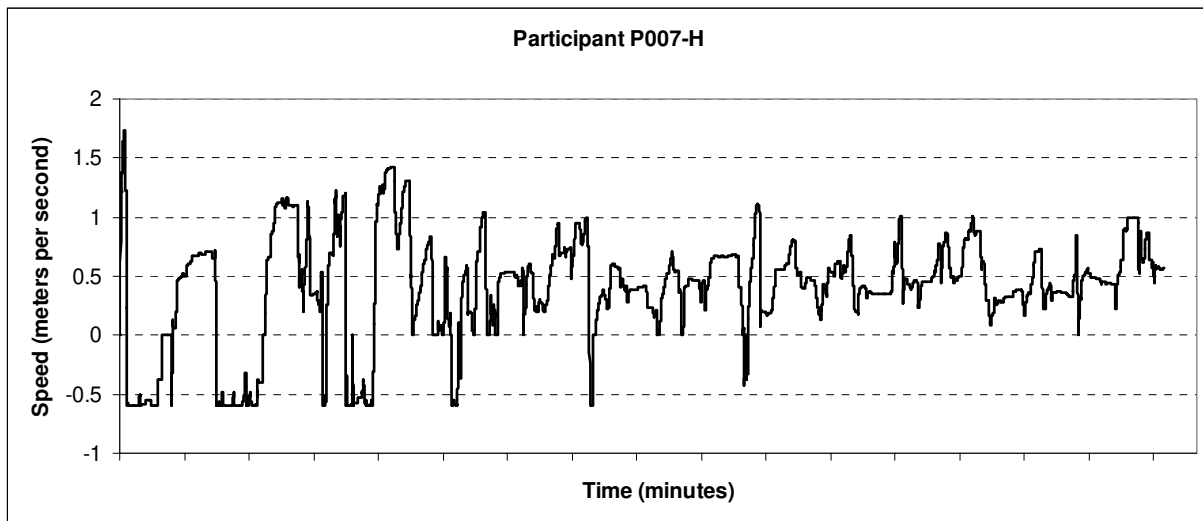
Figure 12: Typical participant speed (meters per second).

Figure 13 plots a randomly selected participant's body rotation as a function of time in the environment. Body rotation was the dependent variable for the passability experiment. This indicates that this participant was not typically or randomly rotating, but was rotating at discrete measurable times.
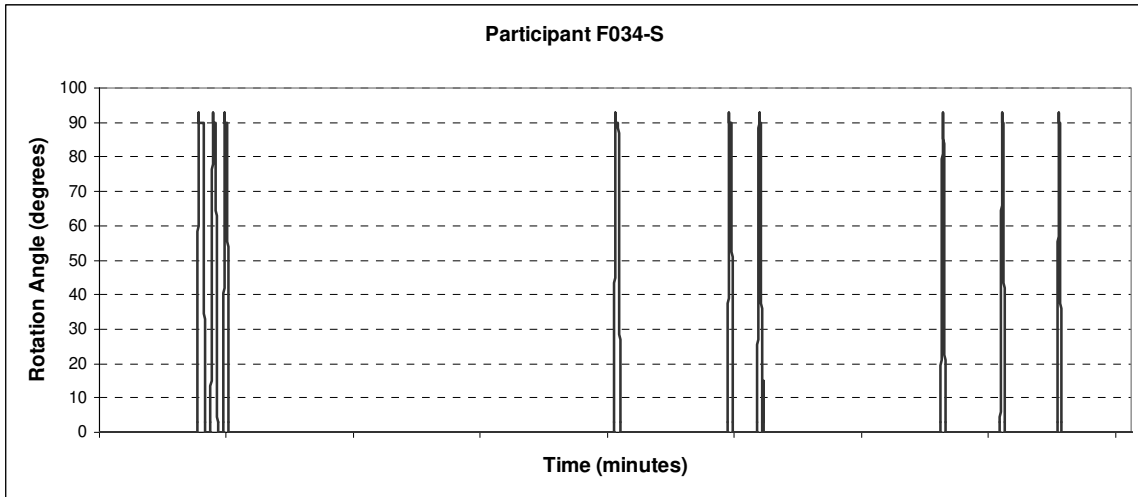
Participant F034-S

Figure 13: Typical participant rotation (degrees to the left)

Figure 14 plots a randomly selected participant's position on the horizontal plane in the virtual environment. In Renderware, the horizontal plane is actually the X-Z plane, with positive Z down and positive X to the right. Position was the dependent variable for the catchability experiment. Position indicates if the participant exited out of the left (indicating that the ball could have been caught) or the right (indicating that it could not have been caught) passageway.
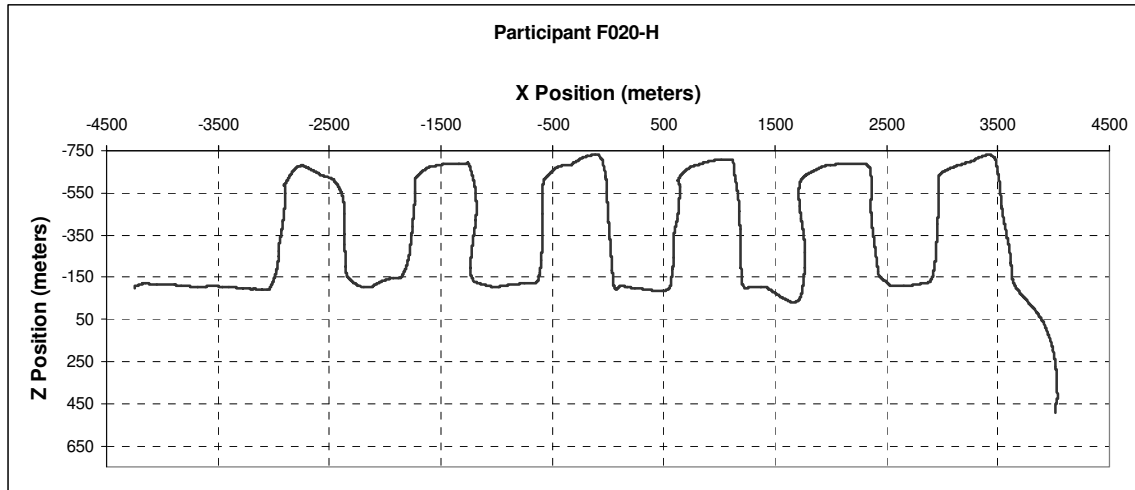
Figure 14: Typical participant position on the horizontal plane.

Figure 15 plots a randomly selected participant's altitude as a function of time in the virtual environment. In Renderware, altitude is actually position along the Y axis and an altitude of 60 is ground level. Altitude was the dependent variable for the flyability experiment. As was the case for body rotation, Figure 19 indicates that this participant was not typically or randomly flying, but was flying at discrete measurable times. Taken together, this preliminary analysis indicated that it would be feasible to test the hypotheses with the data collected. However, this analysis indicated that the volume of data collected in all the runs was too large to directly analyze as a whole. Data reduction was thus necessary before conducting the across runs analysis. The data reduction is discussed further in the next section.
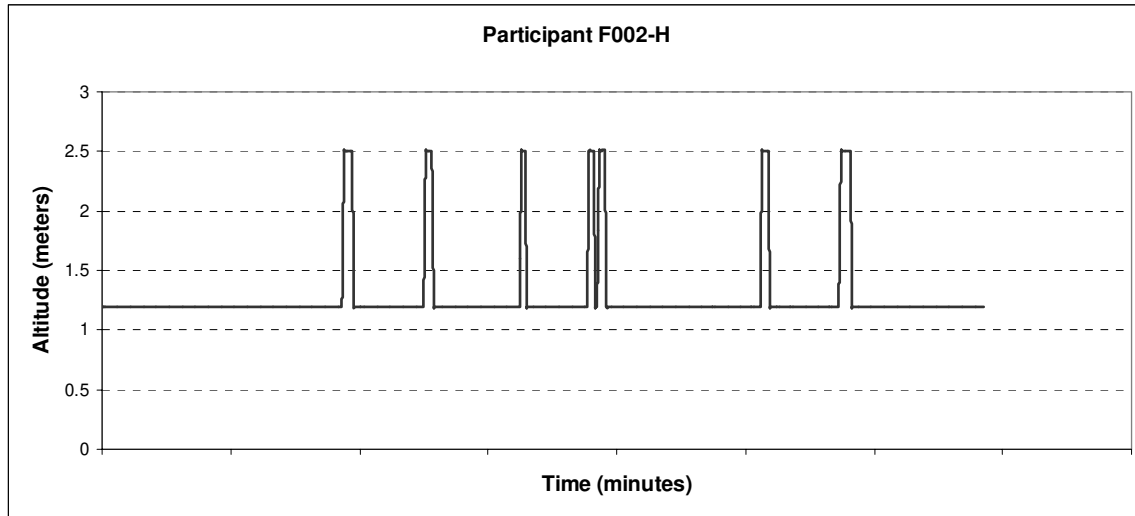
Participant F002-H

Figure 15: Typical participant's altitude at eye point (meters).

Data Reduction

The second analysis of measured behavior focused on testing the study hypotheses concerning whether or not participants perceived a given affordance.

Data reduction focused on condensing the raw data into those epochs that could be used to test the hypotheses. Fortunately, the nature of the behaviors to be measured meant that only transitions between rooms were of particular interest. For example, in regards to passability, the dependent variable of body rotation would be expected to be most informative when transitioning from room i to room $i+1$ because this is when the participant would perceive that rotating would ease the transition. Figure 16 illustrates this point by plotting the transition measured in F020-H's transition from Room 7 to 8 (a passability room). The participant clearly began and completed rotation well in advance of exiting the room, maintained the rotation through the exit, and then rapidly released the rotation after the exit. Likewise, the dependent variable of position would be expected to be most informative for catchability because this is how the participant indicated if the

88

ball was judged catchable. The participant's judgment as to the catchability of a ball is indicated by selection of one of two doors on the wall transitioning from the catchability room to the next room. Finally, in regards to flyability, the dependent variable of altitude would also be expected to be most informative when transitioning between rooms because this is when the participant would perceive that flying would ease the transition. The implication of this realization is that the raw data could be substantially reduced before analysis, perhaps to the single frame indicating room transition.
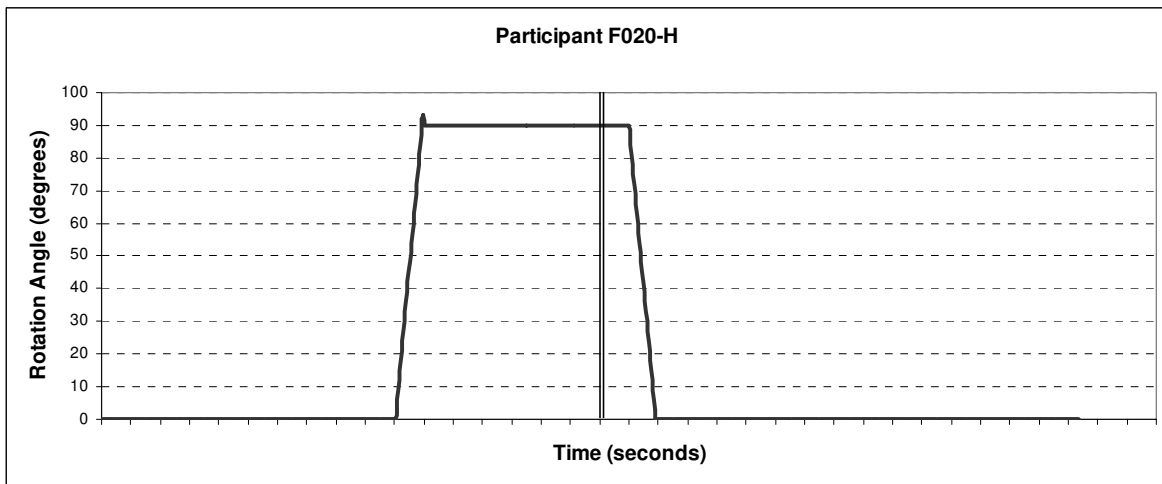
Figure 16: Typical room transition event.

Of course participant's can make mistakes. First, they may execute the expected behavior too early or too late. In the case of passability, this would amount to rotating and releasing *before* exiting or rotating *after* exiting). As the passageways are always wider that the user, there is almost no penalty for this mistake. The exception is alignment error, which occurs when the participant is so misaligned with a passageway as to collide with the wall instead of passing through the passageway. Rotation makes the virtual body narrower and therefore able to slip through passageways with more alignment error than if not rotated. Flyability may generate an analogous behavioral mistake to

passability. In the case of catchability, the participant may exit the wrong passageway, for example exiting the *right* passage when the participant judged the ball *catchable*. A second kind of mistake is a control selection error. As explained in the protocol defined in Appendix A, participants controlled body rotation and altitude by depressing mouse buttons. It is possible that participants might have confused the two control buttons, flying when rotating was intended or visa versus. This error could affect the results only in passability and flyability rooms -- catchability rooms do not require special control inputs. Finally, the participants could make a third kind error, a control input error. This would result from a participant selecting a mouse button when no control input was intended. Again, this error could affect the results only in passability and flyability rooms as catchability did not require special control inputs.

Based on the foregoing discussion, the raw data were reduced through a constructed computer program to 12.5 megabytes, a 20:1 reduction. The program extracted several frames of data around each room's transition, and constructed a file capturing the results for all users for each room. Appendix C presents the reduced data set for each task room, and the behavior conclusion for the affordance being considered in that task room. The reduced results were inspected by hand for the errors discussed, which revealed several occurrences. The major error observed was small rotation angles, therefore the analysis adopted the rule that rotation angle had to exceed 15 degrees to be considered an intentional rotation. The rate of occurrences of the other errors was considered too small to justify adoption of additional interpretation rules. Table 18 summarizes the tests for the perception of the affordances that resulted at this stage of the analysis.

Table 18: Tests for perception of each affordance.

Affordance	Indicating Behavior	Test for Behavior
Passability	Body rotation	Rotation angle greater than 15 degrees upon exiting
Catchability	Position (as compared to room center)	Exiting the room's left door
Flyability	Flight	Altitude greater than ground

Analysis Across Runs

Comparison of participants' perception of each affordance in the VE to the perception of the affordance typically found under similar circumstances in the real world (as defined by previous studies, see Chapter 2) indicated whether a given affordance had been appropriately enabled or not. The experiment collected data regarding the participant's behavior against predicted behavior. The independent variables included circumstances that in the real world would have evoked the affordances under investigation, and also presented various visual and auditory cueing that the conceptual model development suggested might lead to evoking the affordance. Analysis of the data shows whether or not these cues were effective in evoking the affordances under the tested conditions. This means that the first consideration in the across run analysis was the effect of the independent variables on the participant's behavior against predicted behavior.

The second consideration was the magnitude and significance of these effects, and the two way interaction of these effects. The calculation of the magnitude and significance of the main effects and two way interactions followed the approach laid out in Box et al. (1974). The present research adopted a 2_{IV}^{4-1} design with many replications for each of the experiments, which raised two main implications for interpretation of the results. The first implication was that main effects were confounded with three way interactions, and two way interactions were confounded with other two way interactions. The second implication was for the computation of the standard error, which was

a key decision in the calculation of the significance of effects. The most common approach for computing standard error is to assume that the highest order interaction is not significant, and to use the value of that interaction as an estimate of standard error. However, the experimental design adopted in the present study was a fractional factorial, which brought into question an assumption about the significance of higher order interactions. The recommended approach in such circumstances is to estimate standard error from the variance between replications (Box et al, 1974, p. 319). This was the approach adopted in the present analysis. Finally, the adopted approach selected three times the standard error to be the level at which an effect or interaction was judged significant.

Passability Analysis

Table 19 summarizes the measured behavior as compared with predicted behavior for the passability experiment. Significant effects, i.e. those calculated values which fell within a one-sided 95% confidence interval of the predicted fraction rotating for the sample size collected, are marked with an asterisk and **bolded**. The prediction and predicted fraction rotating columns indicate what participants experiencing the given configuration in the real world would be expected to do. These predicted results, which were derived from Warren and Whang (1987), indicate that most participants in the real world would not rotate when presented with a wide door (i.e., one greater than 1.3 times their shoulder width), and most would when presented with a narrow door. The remaining columns indicated what members of each participant group actually did in the VE reported as fraction rotating. Fraction rotating was calculated as the number of participants who rotated in each treatment divided by the total number of participant exposed to that treatment. The Baseline (no cues) participant group's response is as predicted by Stappers (1999), namely that passability in a VE was inaccurately perceived, with only 10-50% rotating in the baseline VE

conditions in which rotation was anticipated due to passage width and 30-40% rotating when it was not expected. The Preliminary (i.e., pilot study) participant group showed a more consistent and somewhat improved perception of the passability affordance, with 55-65% making the expected rotation decision during VE conditions in which rotation was anticipated and 15-25% rotating when it was not expected. The Final (i.e., formal study) participant group showed even greater consistency and improved perception in perceiving this affordance over the preliminary group, with 77.4-81% making the correct rotation decision and 17.9-26.2% rotating when it was not expected. The Alternate (VE configurations presented in a different order) participant group showed erratic behavior, with 0-66.7% making the correct rotation decision and 0-33.3% rotating when it was not expected; with this effect likely being due to sample size. The Header (passageways have a top) participant group was less consistent than the formal group but still had a high level of perception of this affordance, with 60%-80% making the correct rotation decision and 0-40% rotating when it was not expected. Future research is required to determine if it is best to provide a header or not on passageways through which one is trying to afford passability.

Table 19: Fraction displaying behavior as compared to prediction for passability.

Trt Cond.			Fraction Rotating				
(See Table 16)	Predic-tion	Predicted	BASE-LINE	PRELIM-INARY	FINAL	ALTER-NATIVE	HEAD-ER
1	most rotate	0.800	0.500	0.600	* **0.798**	0.000	* **0.800**
2	few rotate	0.200	* **0.300**	* **0.200**	* **0.179**	* **0.333**	* **0.200**
3	few rotate	0.200	0.400	* **0.150**	* **0.214**	* **0.000**	0.400
4	most rotate	0.800	0.300	* **0.550**	* **0.774**	* **0.667**	* **0.800**
5	few rotate	0.200	0.400	* **0.150**	0.262	* **0.000**	* **0.000**
6	most rotate	0.800	0.100	* **0.650**	* **0.810**	* **0.667**	* **0.600**
7	most rotate	0.800	0.200	0.600	* **0.798**	0.333	* **0.800**
8	few rotate	0.200	0.400	* **0.250**	* **0.238**	* **0.000**	* **0.000**

* - Calculated value is within one-sided 95% confidence interval, $\alpha = 0.05$.

Table 20 summarizes the calculated magnitude and significance of each main effect and their two way interactions on passability for the relevant participant groups. Significant effects, i.e., where the Effect is greater than three times the Standard Error, are marked with an asterisk and **bolded**. For the Final participant group, the passageway width was significant, as were the peripheral and bar cues. All two way interactions were significant. Realizing that rotation should only occur when the passageway is narrow and that the Baseline group showed that in the absence of cues, the participants were unable to accurately realize passability, the implication of the significant two way interaction is that the presented cues are sources of the participant's increased response to passageway width and therefore improved realization of passability. The Preliminary and Header groups reflect similar results. The failure of the Alternative group to reach significance for the bar

cue is troubling; however this is likely a consequence of the small sample size. The Alternative

group provides five samples, and the power of the resulting test is only 0.19, whereas the Final

group with 86 samples has a power of one, the Baseline group with ten samples has a power of 0.64,

and the Preliminary group with 20 samples has a power of one. The Header group, which provides

three samples, has a power comparable to the Alternative group but found the bar cue to be

significant. The Alternative configuration would require 24 total samples (19 more) to provide the

same power as the Baseline group assuming constant variance.

Table 20: Effects of main factors and two-way interactions on passability.

Effect	Baseline	Preliminary	Final	Alternative	Header
Bar cue (A)	N/A	* **0.038**	* -0.018	-0.100	* **0.333**
Form cue (B)	N/A	-0.013	-0.006	0.100	0.000
Peripheral Cue (C)	N/A	* **0.038**	* **0.036**	* **-0.200**	0.000
Passage width (D)	* **0.100**	* **-0.413**	* **-0.571**	* **-0.600**	* **-0.333**
A-B or C-D	N/A	-0.013	* **0.018**	-0.100	* **-0.167**
A-C or B-D	N/A	* **0.038**	* **0.012**	0.000	* **-0.167**
A-D or B-C	N/A	* **0.038**	* -0.012	0.000	* **-0.167**
3x Standard Error	0.068	0.031	0.006	0.105	0.167

- Calculated as > 3x standard error.

Catchability Analysis

Table 21 summarizes measured behavior as compared with predicted behavior for the

catchability experiment. Significant effects, i.e. those calculated values which fell within a one-sided

95% confidence interval of the predicted fraction rotating for the sample size collected, are marked

with an asterisk and **bolded**. The prediction and predicted fraction catching columns indicate what

participants experiencing the given configuration in the real world would be expected to do. These

predicted results, which were derived from Oudejans et al. (1996), indicate that most people will judge a ball catchable if it lands within a circle whose radius is 1.2 times their actual catchable range, i.e., they over estimate. The predicted values in the table therefore are driven by the experimental configuration's value for shot range, either catchable or not. The remaining columns indicated what members of each participant group actually did in the VE reported as fraction judging the ball as catchable. The remaining columns indicate how the various groups actually judged the ball in the virtual environment. The Baseline (no cues) participant group's response indicates that participants were largely unable to judge the ball correctly, with 40-90% of participants judging catchable balls as such and 30-90% misjudging uncatchable balls. This is an expected result as the experimental design anticipated that catchability would not be realized in conventionally designed VEs much as passability is not. The Preliminary participant group showed a significant improvement, with 80-95% of participants judging catchable balls as such and only 0-15% misjudging uncatchable balls. The Final participant group also did well, with 88-96.4% of participants judging catchable balls as such and only 11.9-22.6% misjudging uncatchable balls. The Final 021-043 group, which had a modified thud cue, demonstrated marginal improvement over the Final group at large, particularly with respect to judging uncatchable balls, with only 4.3-17% misjudging such balls. The Alternative group showed results comparable with the Final group. All four of these groups found that the response to configuration 15 (no stick cue, thud cue, peripheral cue, and catchable) fell outside of the 95% confidence interval for the predicted results. The data provide no strong indication of why this result occurred. Reports from participants about the distracting nature of the peripheral and thud cues may mean that participants were too distracted to make a valid judgment as to the ball's catchability with this particular combination. Future research should carefully address the best way to combine such cues.

Table 21: Fraction displaying behavior as compared to prediction for catchability.

Trt Cond. (See Table 16)	Pred-iction	Predicted	BASE-LINE	PRELIM-INARY	FINAL All	FINAL-021-043	ALTER-NATIVE	HEAD-ER
9	Most Catch	0.800	0.500	* **0.850**	* **0.881**	* **0.894**	* **1.000**	* **1.000**
10	Few Catch	0.200	0.500	* **0.150**	* **0.226**	* **0.170**	* **0.000**	* **0.200**
11	Few Catch	0.200	0.900	* **0.000**	* **0.119**	* **0.043**	* **0.000**	* **0.000**
12	Most Catch	0.800	* **0.900**	* **0.800**	* **0.964**	* **0.979**	* **1.000**	* **1.000**
13	Few Catch	0.200	0.400	* **0.050**	* **0.143**	* **0.085**	* **0.000**	* **0.000**
14	Most Catch	0.800	* **0.900**	* **0.950**	* **0.964**	* **0.979**	* **1.000**	* **0.800**
15	Most Catch	0.800	0.400	0.000	0.119	0.085	0.000	* **0.600**
16	Few Catch	0.200	0.300	* **0.100**	* **0.179**	* **0.064**	* **0.000**	* **0.200**

* - Calculated value is within one-sided 95% confidence interval, $\alpha = 0.05$.

Table 22 summarizes the calculated magnitude and significance of each main effect and their two way interactions on catchability for the participant groups. Significant effects, i.e., where the Effect is greater than three times the Standard Error, are marked with an asterisk and **bolded**. Table 22 distinguishes between the Final-All and Final 021-043 groups, because the thud cue was modified as a result of observations during the experimental runs as discussed earlier. The Baseline, Final, and Final 021-043 participant groups found all of the main effects (cues) significant. Likewise, all two way interactions were significant. Realizing that the catchable judgment should only occur when the shot range was long, and that the Baseline group showed that, in the absence of cues, participants were generally unable to accurately realize catchability, the implication is that the affording cues were sources of the participant's more accurate response to shot range.

Table 22: Effects of main factors and two-way interactions on catchability.

Effect	Baseline	Prelim-inary	Final All	Final 021-043	Alter-native	Header
Stick Cue (A)	N/A	* 0.275	* 0.268	* 0.271	* 0.150	* 0.250
Thud Cue (B)	N/A	* -0.275	* -0.208	* -0.239	-0.050	* -0.250
Peripheral Cue (C)	N/A	* -0.175	* -0.196	* -0.218	* -0.150	* -0.250
Shot Range (D)	* -0.150	* -0.575	* -0.565	* -0.644	* -0.750	* -0.750
A-B or C-D	N/A	* 0.175	* 0.185	* 0.186	* 0.150	* 0.250
A-C or B-D	N/A	* 0.225	* 0.173	* 0.165	0.050	* 0.250
A-D or B-C	N/A	* -0.175	* -0.196	* -0.218	0.050	* -0.250
3x Standard Error	0.061	0.012	0.004	0.004	0.068	0.000

* - Calculated as > 3x standard error.

Flyability Analysis

Table 23 summarizes the measured behavior as compared with predicted behavior for the flyability experiment. Significant effects, i.e. those calculated values which fell within a two-sided 95% confidence interval of the predicted fraction rotating for the sample size collected, are marked with an asterisk and **bolded**. A two-sided confidence interval is appropriate, because the flying predictions occur at three levels. The prediction and predicted flying columns indicate what participants experiencing the given configuration in the real world would be expected to do. Flyability is not an affordance that naturally exists for humans, so the circumstances under which it is enabled were unknown prior to this study. This is the reason that the flyability experimental configuration includes two object properties (window height and width). Whereas the passability experiment configuration could leverage from Warren and Whang (1987) that passageway width was the critical object property and the catchability experiment could leverage from Oudejans et al. (1996) that shot range was the critical object property, the flyability experiment had no such prior

results. The conceptual model postulated that flyability was a spatial affordance; therefore the predicted results are postulated based on parallels in flyability to passability. As a result, the flyability experiment has three levels of prediction under the assumption that there may be some interaction between window height and width. The passability studies discussed (Warren, 1984; Warren & Whang 1987; Marik, 1987) all suggest object properties along the vertical axes (frontal or sagittal) of the observer, such as passage width and stair height. Therefore, the predictions are that participants will be more likely to fly when faced with a low, wide window, and less likely to fly if a window is either narrow or high, and still less likely if the window is both high and narrow. The remaining columns indicated what members of each participant group actually did in the VE reported as fraction flying. The Baseline (no cues) participant group responded strongly to the window height object property – configuration four through eight all have the window height set to "high", and all of these values for the Baseline group fall within the 95% confidence interval. This is strong evidence that height to fly over is a critical object property for flyability. The Preliminary participant group showed results inconsistent with the Baseline, implying that the cues added had an effect but not the desired one of bringing measured behavior in line with predicted behavior (only three configurations are within the 95% confidence interval). The Final participant group showed significant improvement in correlating observed behavior with predicted behavior (six configurations are within the 95% confidence interval). The failure of the Final group to exhibit every aspect of the predicted behavior is not of particular concern, since predicted values were not based on prior studies. Flyability is not an affordance in the real world, so there were no studies on what constitutes an evoking circumstance prior to the present research, or what its threshold values are, as opposed to passability and catchability. The results provide strong evidence that window height and width are evoking circumstances for flyability, and provide a basis for predicting their threshold values for enabling realization of flyability. For example, changing the predicted fraction

of 'few' flying from 0.200 to 0.300 would have resulted in the Final group perfectly reflecting

predicted behavior. These results suggest that flyability is readily afforded in VEs, which is

interesting given that it is a supernatural phenomenon.

Table 23: Fraction displaying behavior as compared to prediction for flyability.

Trt Cond. (See Table 16)			Fraction Flying				
	Prediction	Predicted	BASE-LINE	PRELIM-INARY	FINAL	ALTER-NATIVE	HEADER
17	Some Fly	0.500	0.100	* **0.468**	* **0.468**	* **0.000**	* **0.200**
18	Most Fly	0.800	0.200	0.450	* **0.726**	* **0.667**	* **0.400**
19	Most Fly	0.800	0.300	0.400	* **0.655**	0.000	* **0.200**
20	Most Fly	0.800	0.400	0.400	* **0.679**	0.000	* **0.400**
21	Some Fly	0.500	* **0.300**	* **0.450**	* **0.429**	* **0.667**	* **0.600**
22	Few Fly	0.200	* **0.100**	0.500	0.393	* **0.333**	* **0.200**
23	Few Fly	0.200	* **0.200**	0.600	0.440	* **0.333**	0.600
24	Some Fly	0.500	* **0.600**	0.200	* **0.393**	* **0.333**	0.000

* - Calculated value is within one-sided 95% confidence interval, $\alpha = 0.05$.

Table 24 summarizes the calculated magnitude and significance of each main effect and their

two way interactions on flyability for the relevant participant groups. Significant effects, i.e., where

the Effect is greater than three times the Standard Error, are marked with an asterisk and **bolded**.

The Baseline group demonstrated that in the absence of cues, participants were unable to realize

flyability as predicted (only 2 configurations < 3 * Standard Error). The Preliminary group, which

had prototypes of the cues present, demonstrated a realization of flyability much more in line with

the predicted values (5 configurations < 3 * Standard Error). The Final participant group showed

consistent improvement with every configuration group in line with the predicted result. This

demonstrated that the modifications made after the preliminary study better enabled the realization

of flyability as predicted. The single best example is the dramatic improvement of the magnitude of

the Height effect, which was 2725% greater in the Final as compared to the Preliminary group (-0.218 versus 0.008).   All two way interactions in the Final group were significant. The implication is that window height and size are primary determinates of flyability (much as passageway width is for passability), and that wings and peripheral cues are sources of a participant's decision to fly. The Preliminary, Alternative, and Header groups do not reflect similar results. These effects are weak (relative to those measured in passability and catchability) and thus may be related to the small sample size. The power of the Alternative group (sample size 5) is 0.05 for window height; the power of the Header group (sample size 3) is 0.06 for wings. The Alternative group would require a total of 55 samples (50 more) and the Header would require 129 total samples (126 more) to achieve the same power as the Baseline sample assuming constant variance.

Table 24: Effects of main factors and two-way interactions on flyability.

Effect	Baseline	Preliminary	Final	Alternative	Header
Wings Cue (A)	N/A	* **-0.092**	* **0.050**	* **-0.150**	0.083
Peripheral Cue (B)	N/A	* **-0.067**	* **0.038**	-0.050	* **-0.250**
Height of Window (C)	0.050	0.008	* **-0.218**	0.050	* **0.250**
Width of Window (D)	* **0.150**	* **-0.117**	* **0.056**	-0.050	* **0.250**
A-B or C-D	* **0.550**	* **-0.108**	* **-0.062**	-0.050	-0.083
A-C or B-D	N/A	* **-0.083**	* **-0.091**	* **-0.350**	* **-0.250**
A-D or B-C	N/A	-0.008	* -0.032	-0.050	0.083
3x Standard Error	0.058	0.037	0.008	0.135	0.208

- Calculated as > 3x standard error.

Presentation Form Analysis

The experiment also supported a comparison of the perception of the tested affordances in two different presentation media: a HMD or a project screen. Table 25, shows the t-test value

computed for each affordance between the HMD and Screen presentation media. The difference between the HMD and the Screen presentation media were found to be significant (t-test, α=0.05), whereas the difference was not found to be significant in the flyability experiment.

Table 25: Affordances impact on presentation media.

Affordance	t - calculated	t - table	Conclusion	Interpretation
Passability	*3.704	1.895	Reject	HMD is different than Screen
Catchability	*2.744	1.895	Reject	HMD is different than Screen
Flyability	0.953	1.895	Fail to Reject	HMD is not shown to be different than Screen

* p<0.05

A final issue concerns the participant's awareness of the cues presented. This awareness was not measured directly, but was tested by survey. Figure 17 shows the percentage of participants reporting that a particular cue form was noticed and the corresponding 95% confidence interval, as derived from the responses to the "Affordances in Virtual Environments – Cue Perception Questionnaire". The "other" category addresses participants reporting cues which were not actually present in the task room. The data indicate that typically less than half of the participants noticed any specific cue. The two exceptions are 56% of the participants noticed the passability peripheral cue and 51% noticed the catchability shot range cue. Forty seven percent of the participants noticed the flyability window height cue. In regards to passability, significantly more participants noticed the peripheral cue than the form cue. In regards to catchability, the shot range was noticed by significantly more participants than the stick, thud, and other cues. In regards to flyability, no participant reported noticing the flyability wing cue whose 95 confidence interval does not overlap with any other flyability cue. The height cue for flyability was noticed by significantly more

participants than any other flyability cue. Note that other phantom cues were noticed about the same rate as cues actually present, indicating that the actual cues were not an important source of confusion or distraction for participants. The most common non-existing cue reported was the reporting of a different affordance cue, such as the presence of a sound cue for passability. Participants also reported non-existing cues such as changes in color, light, shading, or size of apertures. Several participants reported "never" or "always" performing a function such as rotating, judging catchable, or flying, but the actual data show that every participant varied their behavior to a greater or lesser extent (see Tables 19-24).
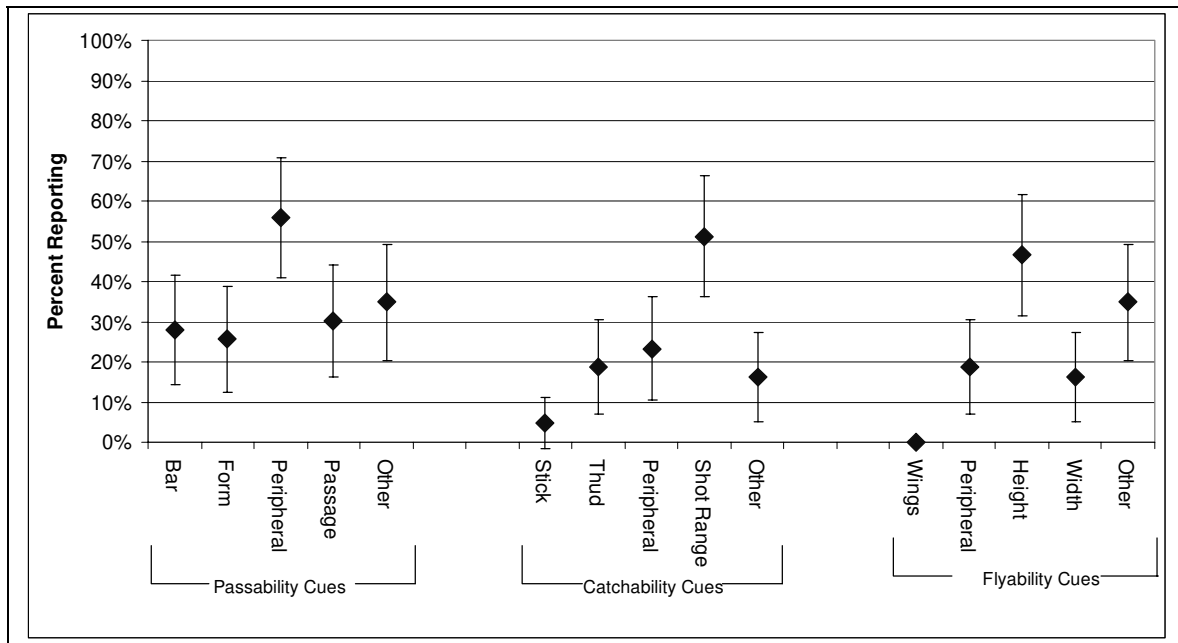
Figure 17: Cues noticed by participants (confidence interval, $\alpha=0.05$).

CHAPTER 5: DISCUSSION

The discussion proceeds from the most specific and least general implications of the study to the most general implications. It begins by exploring the implications of the experiment's results for the six hypotheses developed in the Background chapter, which was the immediate objective of this study. Then, the discussion explores the implications of the experiment's results for the more general question of sensory substitution schemes. Finally, the discussion explores the implication of the experiment's results for the general question of design enabling affordances.

Implications for the Hypotheses

The objective of the present research was to enable the perception of affordances in virtual environments. Toward this end, the realization of three affordances was considered: passability, catchability, and flyability. Two hypotheses were developed for each affordance in turn.

Passability Hypotheses

The first hypothesis developed regarding the passability affordance was:

Hypothesis: Visual cues for body stature substituting for absent multimodal sensory stimulation and body stature information can enable the realization of the passability affordance in virtual environments, as confirmed by testing for the ratio of 1:1.3 for comfortable passability.

The results generally support this hypothesis. The results for the baseline participant group (see Table 20), which were not provided with cues to enhance the realization of affordances, support the position that participants generally do not correctly perceive the affordance of passability when

104

simply presented with visual information about passageways (e.g., the width of a doorway). These results are in line with Stappers' (1999) findings that VE participants do not perceive passability in conventionally designed VEs in a manner similar to that experienced in the real world. For the formal group (see Table 19), which was provided with substitution cues, two of the visual cues tested, the bar and the peripheral cues, significantly affected participant's passability behavior bringing it in line with behavior observed in real world situations, with participants rotating their body when passage widths were less than 1.3 times their body width (Warren & Whang, 1987). This is a very encouraging finding, suggesting that visual cues can enable the correct realization of passability. This could be particularly important for those attempting to train psychomotor skills in a virtual environment, such as a Marine's behavior during a room clearing exercise.

The fact that the bar cue was not effective in the alternative VE (see Table 19), could suggest that cues may have limited generalizability in their effectiveness to realize affordances. This is a troubling finding, as it suggests that one would have to test the effectiveness of a given cue in each and every VE it is to be used in. An alternative interpretation of this result is that it is simply an effect of small sample size, which is supported by the power analysis as discussed.

The fact that the form cue was not effective (see Table 19), is troubling, because form cue is generally regarded as more realistic that the bar cue, and the expectation is that more realistic cues lead to improved realization of the affordance. An alternative explanation is that the participants found the form cue disconcerting because it presents the head cue below eye level, close to knee level. In this case, the increased realism of the cue may work against its efficacy as the head would not be correctly placed. Observers might have had trouble interpreting the cue as indicating head and shoulders, because to do so they would have to translate the cue from its presentation at knee level to head level. This latter interpretation is supported by the fact that the magnitude of the form cue effect as on the border of significance (an effect of -0.600 versus the level of significance of

0.600, see Table 20), indicating that it had some effect on users but significantly less than for the bar or peripheral cues.

The Background chapter argued that there are three key sources of information required in order to realize the passability affordance, and that the last is impoverished in a VE (see Table 5). Specifically, knowledge of shoulder width, which arises from experience and ongoing kinesthetic and vestibular mode stimulation, is absent. The bar and peripheral cues were shown effective by the passability experiments in substituting visual data for this missing kinesthetic and vestibular stimulation (see Table 20). This supports the supposition based on Storms (2002) and Shimojo and Shams (2001) that the strong association between spatial perception and visual stimuli can indeed be exploited to enable the perception of passability.

The second hypothesis developed regarding the passability affordance was:

Hypothesis: An appropriate minimal form for visual cues of body stature can be found, as confirmed by measuring threshold responses to a variety of cues.

The results indicate that the bar and peripheral cues may be able to serve as minimal forms for a visual cue of body stature (see Table 20). This directly supports the conceptual model (see Figure 4) developed, which contended that passability is not correctly perceived in VEs because VE users do not perceive their own shoulder width, and a minimal amount of information providing this cue would enable perception of the passability affordance.

However, the form cue did not afford passability (see Table 20). The form cue consisted of a 3-dimensional simplified form of a head, neck, and shoulders; whereas the bar cue consisted of a simple rectangular bar the width of the participant's virtual shoulders, and the peripheral cue consisted of hashing outside the width of the shoulders. In some respects the outcome is surprising because the form cue would typically be considered more realistic than the bar cue, and the usual

expectation is that more realistic cues improve performance (Durlach & Mavor, 1995; Cutting, 1997). On the other hand, the form cue includes information not relevant to realizing passability such as the height of the head off of the shoulders. The efficacy of the bar and peripheral cues is most promising, as it indicates that non-specific cues that simply indicate what is "out of bounds" have the ability to realize the passability affordance.

The experiment findings produce implications for VE designers seeking to enable the realization of passability in terms of things a designer can easily control: 1) the properties of objects in a VE; 2) characteristics of the user in the VE; and 3) the action capabilities of the user in the virtual environment. The results imply that a critical object property or evoking circumstance for passability in VEs is passageway width, because when the width was less than the virtual shoulder width, the passability affordance was realized. This is consistent with real world studies (Warren, 1984; Warren & Whang 1987; Marik, 1987). One could argue that the edges around passageways, rather than the passageway width, are the critical object properties eliciting the passability affordance. In the present study, the majority of edge cues derived from the simple intersection of the wall with the floor, with no particular emphasis. Further, the far wall, i.e., the wall beyond the one with the passageway, was the same color and texture as the passageway wall, so there was no drastic contrast used between passageways and surrounding wall object properties. Thus, the findings support the premise that passageway width is a critical object property for realizing the passability affordance.

In terms of the physical characteristic required for realizing passability, the comparison of the baseline and formal groups suggests that shoulder width is critical to enable the realization of passability. When participants were presented with visual cues as to the shoulder width of their virtual body, they tended to rotate their virtual bodies when passageway width was less than 1.3 times the cued shoulder width; far fewer participants chose to rotate when these cues were not

provided. In the present study, the simplest physical characteristic cue that proved effective was a horizontal bar, located at the participant's virtual body position, which rotated around the vertical axis to indicate the participant's degree of rotation. Designers should consider endowing their virtual avatars with cues about width in order to afford passability.

Finally to enable the realization of passability, the VE must provide a means for users to rotate the virtual body. In the present study, the rotation action capability was provided by depressing the left mouse button. While this approach was effective, it is not the most intuitive of approaches, as it involves a metaphoric (i.e., left button=rotate) rather than a direct mapping (e.g., turn of one's actual body evokes the same effect in one's virtual body). It is likely that providing this action capability by harder (e.g., depressing two buttons) or easier (e.g., measuring head rotation angle) would change the magnitude of the cueing effects.

Catchability Hypotheses

The first hypothesis developed regarding the catchability affordance was:

Hypothesis: Visual and auditory cues for acceleration and velocity substituting for absent multimodal sensory stimulation and action capabilities information can enable the realization of the catchability affordance in virtual environments, as confirmed by testing for the 1:1.2 ratio of actually catchable balls to those perceived catchable.

The results generally support this hypothesis. The results for the baseline participant group indicated that participants can correctly judge catchability in the absence of cueing with a low level of accuracy (see Table 22); however, adding cues improves the quality of such judgments. More specifically, the results for the baseline group demonstrate that in the absence of substitution cues participants were able to weakly realize the catchability affordance as evidenced by the decision to rotate (an effect of -0.150), but much more strongly realize the affordance in the presence of the

substitution cues (an effect of -0.644). While the visual cues (stick and peripheral cues) were effective in realizing the catchability affordance in both the formal VE and the alternative VE, the thud was only effective in the formal virtual environment (see Table 22). This is surprising given the relationship between the auditory modality and temporal perception and suggests that the optimal design of an auditory cue for realizing the affordance of catchability is yet to be identified. It also could suggest that the temporal component of the catchability task as developed in this study was not as influential as would normally be experienced during a catching drill. To address these concerns, future research should explore different forms of audio cues and their relationship to the realization of temporal affordances. For example, the thud cue implemented in the experiment was actually more of a high pitched "beep". It may be that a cue closer to a footfall would produce a stronger effect. As implemented, the thud cue used the space between thuds as indirectly related to speed (thuds closer together indicated faster speed). It may be that other cues, such as varying pitch with speed, might be more effective.

The argument developed in the Background chapter argued that there are seven key sources of information required to realize the catchability affordance, and that two of these are impoverished in a VE (see Table 6). Specifically, self-velocity and self-acceleration, both of which arise from experience and ongoing kinesthetic and vestibular mode stimulation, are absent. Both visual cues (stick and peripheral) and an auditory cue (thud) were shown effective by the catchability experiment (see Table 22). The effectiveness of the auditory cue is not surprising because the auditory modality is generally highly effective in conveying information when reaction time is essential for effective task performance (Popescu et al., 2002; Storms, 2002). The visual-auditory cue interactions were all significant too, which supports Shimojo and Shams' (2001) point as to the ability of auditory stimuli to intensify visual stimuli. These findings support the supposition developed in the Background

chapter that the strong association between temporal perception and auditory and visual stimuli interaction can be exploited to enable the perception of catchability.

The second hypothesis developed regarding the catchability affordance was:

Hypothesis: An appropriate minimal form for visual and auditory cues of locomotion can be found, as confirmed by measuring threshold responses to a variety of cues.

The results suggest that a range of cues (both visual and auditory) can be leveraged to enable the perception of catchability, which supports this hypothesis. The conceptual model developed implied that auditory information would be the most important source of information for enabling the perception of catchability, therefore the result that visual cues were comparable in their effectiveness to realize this affordance is somewhat surprising. There are a number of possibilities that might explain why auditory information was not more effective– the size of the room, the time available to make the judgment, the relative speed of the intersecting objects and so forth. The cannon balls were shot with velocities that led to their impact within about two to three seconds and traveled no more than eight meters; therefore there was little time to integrate the audio cue. If the situation had permitted a longer period before the ball impacted, it is possible that audio feedback concerning acceleration and self-velocity might have been more significant. Thus, while this substitution aimed at replacing missing exterocepter, interceptor, and propriocepter cues associated with accelerating to catch a ball, the period of bodily movement may have been too short for these cues to act as a movement metronome.

The adjustment of the thud cue after the first twenty runs provides strong evidence as to the minimal level for this cue in particular. The design intent of the cue was to provide thuds, or short sounds, at a slow rate when the participant's speed was low and a faster rate when the participant's speed was greater. The original implementation resulted in an almost flat curve in the range of

speeds actually exercised. The thud cue revision beginning with F-021 produced a curve with a noticeable rate change in the thuds. Although the change in the cue was fairly dramatic, the impact on the effect was not (moving from -0.208 to -0.239, with both effects significant). This suggests that any audio cue related to movement may significantly aid participants in judging the catchability affordance. The slight increase in cue effectiveness, however, suggests there may be some benefit to using noticeable rate changes. Future research should consider if variable rates for auditory cues have the potential to further enhance the realization of the catchability affordance.

The fact that participants could realize the catchability affordance in the absence of the substitution cues indicates that this affordance is not as handicapped as passability by the absence of sensory data in VEs at the boundary values tested. As discussed, catchability should involve a strong temporal component, and the visual sensory information required to make speed judgments (e.g., position in the environment) is present even without the additional audio substitution cues.

The results imply that a critical object property, or evoking circumstance, for catchability in VEs is the height of the ball, which is one of the effects of how the balls where shot out of the cannon. The balls shot as uncatchable had a lower trajectory than the balls shot as catchable, and participants reported cueing off ball height in the cue perception questionnaire. Future research could repeat this experiment with a wider range of trajectories. This cueing off of the trajectory of the ball is consistent with real world studies (Oudejans et al., 1996). One could argue that ball rotation, rather than the ball height, is the critical object property eliciting the catchability affordance. However, the balls in the present study did not include rotation, so it is unlikely that rotation is necessary to enable the realization of catchability. Thus, the findings support the premise that ball height is a critical object property for realizing the catchability affordance.

The comparison of the baseline and formal groups suggests that reach range and self- velocity are the physical characteristics required to realize catchability. When participants were presented with visual cues as to the reach range of their virtual body and visual (a leaning stick) or auditory (footstep sound) cues correlated with the velocity of their virtual movements they tended to have an enhanced sense of catchability as compared to baseline participants who lacked such cues. In the present study, the simplest physical characteristic cue that proved effective was a vertical bar (i.e., stick), located in the frontal plane of the participant's virtual position, which rotated around the horizontal axis to indicate the participant's speed. The "thud" cue, a series of variable auditory "beeps" related to speed, was found to be an effective audio cue. Designers should consider endowing their virtual avatars with such cues in order to afford catchability.

Finally to enable the realization of catchability, the VE must provide a means for users to move their virtual body. In the present study, movement was directly controlled by mouse position. No capability for actually catching such as extending arms, opening hands, or grasping, was provided to the participants. Such action capabilities should be considered in future research.

Flyability Hypotheses

The first hypothesis developed regarding the flyability affordances was:

Hypothesis: Visual cues for space required to fly substituting for absent multimodal sensory stimulation and action capabilities information can enable the realization of the flyability affordance in virtual environments, as demonstrated by users choice of flying when presented with multiple, valid forms of locomotion.

The results generally support this hypothesis. Participants chose to fly without any visual cues (see Table 24), but the presence of visual cues encouraged participants to choose to fly more often and tended to align the decision to fly with situations that made sense, such as in the presence of

lower and wider windows. Both visual cues (i.e., wings and peripheral cues) were effective in

affording flying in the formal VE, however, in the alternate VE only the wings were effective. This

suggests that the wings cue may be the most appropriate cue for affording flying. Further, the

addition of a header seems to have enhanced the perception of the flyability affordance for the

peripheral cue (see Table 8).

The Background chapter argued that there are three key sources of information required in

order to realize the flyability affordance, and that the last is impoverished in a VE (see Table 7).

Specifically, knowledge of spatial requirements for flying, which arises from experience and ongoing

kinesthetic and vestibular mode stimulation, is absent. The wing and peripheral cues were shown

effective by the flyability experiments in substituting visual data for this missing kinesthetic and

vestibular stimulation (see Table 24). This supports Storms' (2002) and Shimojo and Shams' (2001)

supposition that the strong association between spatial perception and visual stimuli can be

exploited to enable the perception of flyability.

The second hypothesis developed regarding the flyability affordance was:

Hypothesis: An appropriate minimal form for visual cues for flying can be found, as

confirmed by measuring threshold responses to a variety of cues.

The results suggest that a range of visual cues (wings and peripheral) can enable the

perception of the flyability affordance, which supports this hypothesis. Flyability is different from

passability and catchability in that it is not an affordance realized in the real world. Therefore, the

object properties, or evoking circumstances, that evoke realization of the flyability affordance are

unknown, whereas it is known that passage width evokes passability and the distance a ball is shot or

thrown (i.e., the "catchable" cue) evokes catchability. It is of interest to discover what evoking

object properties and what physical characteristics are engaged in realizing the flyability affordance.

As the experiment only considered two levels for each factor, it will not be possible to discover an exact ratio such as 1.3: 1 for passability (Warren & Whang, 1987) or 1.2:1 for catchability (Oudejans et al., 1996), but an approximate value can be derived.

The two object properties tested in this study, window width and window height, were selected because they represent the two planes of movement involved in flying as opposed to the single plane for passability. The results demonstrate that both of these object properties were significantly associated with the realization of flyability, although only widow size evoked flyability in the absence of cues (see Table 24).

The preliminary study as compared to the final formal experiments provided valuable information specific to the threshold of the window height cue. The most important change in the flyability cues from the preliminary study to the final study was the change in window height. Window height was not found to be a significant factor for the preliminary group (0.008) but was significant for the final group (-0.218), for which the windows were lowered such that users could see the windows they could fly through. The original values for the window height which failed to evoke flyability were one and one half meters for the low value and two and one half meters for the high value. The revised values after the pilot study results were to one and two meters respectively (see Table 14). The window width was 1.5 meters for the low value and 2 meters for the high, and was not modified throughout the experiment.

It is unknown what physical characteristic forms the appropriate ratio for flyability, however, the choice to fly or not is a choice of locomotion style similar to passability. The passability studies (Warren, 1984; Warren & Whang 1987; Marik, 1987) all suggest physical characteristics along the vertical axes (frontal or sagittal) of the observer, such as shoulder height and knee height. Therefore, this analysis uses eye point as a first approximation for the vertical plane and shoulder

width for the horizontal plane. Eye point in all of the experiments was 1.8 meters and shoulder

width was 0.8 meters. Therefore, the approximate ratio $\dfrac{WindowHeight}{EyePointHeight} = \dfrac{1}{2}$ appears to evoke

flyability. Likewise, the approximate ratio $\dfrac{WindowWidth}{ShoulderWidth} = \dfrac{2.5}{1}$ appears to evoke flyability. Future

studies should investigate the efficacy of these proposed ratios.

Flyability is not like passability and catchability, which are affordances that have been

measured in the real world and thus evidence exists as to their significant object properties, observer

characteristics, and action capabilities. Flyability is not a natural capability of humans, and therefore

the experiment results here are not confirming that cuing can enable the realization of an affordance

in a similar way to affordances in reality; instead the experiment is showing how a VE can enable the

realization of an affordance only present in a virtual environment. This is particularly important as

one major purpose of VEs is to afford things which reality can not.

The experiment's findings imply that the object properties, or evoking circumstances, for

flyability are window height (lower bound) and window width (side bound). Therefore, to enable

the realization of flyability, objects in a VE to be flown through should include edges and gaps that

relate to lower and side-to-side bounds of the passage to be flown through; with initial ratios being

those proposed above (1:2 for window height to eye point eye and 2.5:1 for window width to should

width). Designers should ensure that for objects intended to evoke flying, the lower bounds and

side-to-side bounds are not so high and so tight as to create a burden to fly. The present study

demonstrated that windows whose object properties include a lower sill (i.e., the header, see Table

24) tend to more easily evoke flying; those whose properties include wide aperture also tend to more

easily evoke flying. However, there is some lower bound beyond which the user will not fly –

participants did not choose to fly out of the passageway, despite the fact that its threshold was lower than the lowest window.

The comparison of the baseline and formal groups suggests that shoulder width and eye point height are likely to be, or are strongly correlated with, the physical characteristics required to realize flyability. When participants were presented with virtual wings or peripheral cues they tended to chose to fly more consistently than baseline participants who lacked such cues (see Table 24). In the present study, the simplest physical characteristic cue that proved effective was the wings cue. The wings cue was located above the virtual body' shoulder position, and rotated around the vertical axis to indicate the participant's degree of rotation. Designers should consider endowing their virtual avatars with such cues in order to afford flyability.

Finally to enable the realization of flyability, a VE must provide a means for users to make their virtual body fly. The experiment's findings imply that the implementation of the flying action capability, depressing the right mouse button, was sufficient for realizing flyability. The experiment only tested this one implementation of the flying action capability – and it is likely that environments which require more effort by the participant to fly (e.g., pressing two keys instead of one) would likely find different specific values for the ratios. If the burden created is too great, users would likely choose a different (easier) locomotion mode.

Implications for Sensory Substitution Schemes

The argument developed in the Background chapter proposed that sensory substitution schemes could succeed in replacing missing sensory modality in VEs and result in enabling realization of affordances. The argument proposed that a successful sensory substitution scheme would have to do three things:

1) Replace sensory modalities not represented in the virtual environment.

2)   Outweigh natural stimuli not correlated with the virtual environment.

3)   Exceed response thresholds in the modality used for the substitution.

The sensory substitution schemes adopted by the experiment generally accomplished all three of these goals, as the cues presented successfully enabled the realization of the affordances tested at least in some if not all of the conditions tested. This implies that designers can develop VE designs that exploit sensory substitution schemes that enable realization of affordances as desired; however, it also implies the efficacy of such schemes may not be universal, potentially depending on the cue used or the VE design itself. Further, the results from this study suggest that the failure demonstrated by Stappers (1999), in which participants in a VE did not realize the affordance of passability, may potentially be overcome at least for the affordances and the substitution schemes herein tested.

The experimental results also support the general scheme of providing visual cues substituting for absent modalities when the affordance in question is primarily spatial, and a combination of visual and auditory cues when the affordances is primarily temporal. Visual cues were effective for enabling the realization of both passability and flyability, which depend on cross modal and spatial perceptions. The audio and the visual cues were effective for enabling the realization of catchability, which depends on cross modal and temporal perceptions.

Finally, the experimental results demonstrate that substitutionary cues need not distract or otherwise interfere with users. Asked to report on the cues that they noticed, participants reported noticing cues that did not exist at approximately the same rate as they did cues they actually did exist. One effective cue, the wing cue for flyability, was reported by no user. This should be investigated by further research as to how this cue was effective and not noticed. The wing cue as compared to the other cues was in a different location (located high in the field of view), was a different color

(blue as opposed to peach), and was presented in a different style (somewhat more complex). It is not known from the existing results which of these effects assisted in reducing the impact of the cue while retaining its effectiveness. This is consistent with Rensink et al's (1997) conclusion that observers never form a complete, detailed representation of their surroundings. This result is important because it indicates that design approaches that depend on substituted stimuli may be acceptable to VE users. If participants had noticed the cues, it could have been argued that providing cues via substituted stimuli is distracting from the intended experience in a virtual environment. The survey results indicated that at least some cue forms are generally not noticed by the average user, even though they may significantly affect actual behavior.

Implications for Enabling Affordances In Virtual Environments

The Background chapter synthesized a set of principles, which were asserted to have implications for designers seeking to enable correct perception in virtual environments. The following discussion treats each in turn in light of the present research.

Affordances depend on objects in the environment. This principle was developed as a self-evident observation about different object properties/behaviors resulting in different affordances. The existing affordance literature made this assertion only about objects in the real world, and questioned the ecological validity of virtual worlds such as those induced by paintings. The present research has shown that visual and auditory cues in a VE will in fact lead to the realization of different affordances. Further, the range of participant behavior (i.e., passability, catchability, flyability) in response to the range of cues associated with enabling the realization of a specific affordance demonstrates that this principle applies in VEs as well as reality. Finally, St. Amant (1999) argued that an organism can perceive the same affordance from multiple objects, but some objects provide a stronger (better fit) affordance than others, and the present research

118

supports this supposition. For example, in the passability experiment the response to the form cue was less than the response to the bar cue. This is evidence that the bar cue better fits the passability affordance. The implication is that designers can endow objects with properties that are relevant to an individual's purpose within a VE system and thus afford desired skills and appropriate behaviors.

Affordances depend on the organism's action capabilities. This principle was again developed as a self-evident observation that different action capabilities result in different affordances. Warren (1984), Warren and Whang (1987), Bingham and Muchisky (1992), and Oudejans et al. (1996) all discuss the impact of action capabilities on the perception of affordances. This principle is difficult to establish in the real world because an organism usually possesses a given set of action capabilities, which are not easily extended. There are exceptions at the margins for individuals with extraordinary limitations (such as loss of legs) or abilities (such as double jointed-ness). In contrast, it is possible in a VE to extend significantly different action capabilities to all participants. The example in the present research was flying, and the results of the present study suggest that affording this added action capability results in different participant behavior. Participants chose to fly when presented with cueing that enabled the realization of this affordance. The conclusion is that VE designers may be able to empower users with unusual capabilities and expect them to be used if appropriate cueing information is available.

Affordances depend on physical characteristics of the observer. Warren (1984) , Warren and Whang (1987), Marik (1987), Bingham and Muchisky (1992), Oudejans et al. (1996), and Turvey et al. (1999) all demonstrated that affordances relate to the physical characteristics of the observer. This principle was at risk in VE design, as there was no assurance that participants would readily pick up their virtual characteristics and perceive affordances on their basis. The results demonstrate; however that participants did pick up their virtual characteristics as demonstrated, for example, by the relatively low variance in the passability experiment, and in that there was no correlation between

user height and their decision to rotate. The implication for designers is that they may be able to design cues into the VE from which users will form perceived physical characteristics, and these characteristics may in turn enable the realization of affordances.

Affordances depend on the organism's sources of sensory stimuli. This principle asserts that different senses result in different affordances. As developed in the conceptual model, the applicability of this principle in VEs was particularly at risk, as VEs in their present form are impoverished in multiple sensory modalities. Indeed, the entire experimental design was developed as a method to test hypotheses that substitution of sensory stimuli in present modalities could enable realization of affordances that in reality require stimuli in modalities which are impoverished in virtual environments. The discussion of the results against the formulated hypotheses demonstrated that for the conditions tested, it is possible to provide substitution stimuli, thereby enabling the realization of specific affordances. The implication for designers is that they may be able to substitute stimuli in visual and auditory modalities for impoverished modalities.

Affordances depend on integration of multimodal sensory stimuli. Gibson (1979) Van Der Steen (1996), Wertheim (1994) and Marik (1987) all demonstrated that perception in reality depends on integration of multimodal stimuli. This principle was at risk in VEs, again because VEs in their present form lack sensory modalities essential for realization of important affordances. The present research proposed and the results demonstrate that this deficiency can be overcome by substituting sensory stimuli in present modalities for absent modalities, for example, presenting a visual cue of shoulder width for the missing kinesthetic modality. The conceptual model argued that visual cues should be appropriate to enable realization of affordances which are primarily spatial, and a combination of visual-auditory cues would prove best for affordances which are primarily temporal. As discussed in regards to the catchability hypothesis, the evidence developed in the present research supporting auditory cues for temporal affordances is weak, but this may well be a

limitation of the conditions considered. The implication is that designers may be able to exploit the types of cross-modal interactions that transpire during direct perception in the real world by leveraging sensory substitution schemes that can be enacted when a critical sense cannot be represented in a virtual world.

Affordances arise as the organism learns to act within its environment. This last principle was not particularly at risk, as the literature demonstrates that users can learn to operate virtual environments (Card et al. 1983; Anders, 1999). The present research exploited this principle by employing a "training room" during the initial moments of each participant's exposure. Participants were encouraged to remain in the training environment to experiment with the possible behaviors as long as desired. The low error rates observed (flying when rotating was meant, and so forth) indicate that participants did in fact learn to act appropriately within the virtual environment.

Implications of Interface Display Type

The effectiveness of design artifacts intended to enable the realization of affordances could depend on interface display type. Two affordances (passability and catchability) showed a significant difference between the HMD and Screen displays. In contrast, there was no significant difference between the HMD and screen for the flyability affordance. In regards to passability, participants were somewhat more likely to rotate with the HMD than with the screen. In regards to catchability, participants were somewhat more likely to judge the ball shot as catchable with the HMD as compared to the screen. Since the affordances finding media significant are those that exist in the real world as contrasted with the one that failed to achieve significance (i.e., flyability), it is possible that participants found the HMD a more "real" or immersive experience than the screen. Within this interpretation, the media would not have affected flyability as much because flying as implemented in this VE is an inherently unreal experience. Some participant comments received on

the Cue Perception Questionnaire support this interpretation because participants' actions, regardless of display type were that they: "flew whenever I could"; "flew because it was fun." The implication is that it may be advantageous to incorporate immersive displays to enhance the realization of real-world as opposed to supernatural affordances.

Implications for Virtual Environment Applications

Techniques for enabling the realization of specific affordances in specific circumstances have significant implications for VE applications. The Background chapter developed an argument that the three affordances tested in the present research represent three fundamental kinds of interaction that repeatedly and regularly arise in VE designs: interactions with static elements (passability), interactions with dynamic elements (catchability); and interactions not possible in the real world (flyability). The correct realization of these affordances affects the usability and usefulness of VE applications. For example, a VE implementing an aircraft maintenance trainer requires an accurate realization of passability to ensure that the user will experience the same limitations on access as they will on the real aircraft. A VE interface implementing tools for air traffic controllers, particularly military air traffic controllers, requires an accurate realization of catchability to ensure that the closure rates of different aircraft are correctly understood by the operator. Finally, an interface implementing a VE for data mining, in which a user might virtually fly over and through data, would require an accurate realization of flyability, so that users consistently notice significant datum.

Implications for the Design of Virtual Environments

Table 26 provides a summary of the various preliminary guidelines for the design of VE interfaces that result from the discussion of the experimental results. The guidelines may be classified as either confirming expectations based on current literature on real world affordance

realization, or defining a novel contribution to the literature based on the results of the current study. Future research should focus on further validating these guidelines.

Table 26: Preliminary design guidelines for realizing affordances in virtual environments.

Affordance	Factor	Guidelines	Contribution
Passability	Evoking Circumstances	Provide objects with vertical gaps and edges	Confirms real world affordance behavior
	Physical Characteristics	Provide visual cues as to self-shoulder width when gaps approach the critical ratio of 1.3 passage width to 1.0 shoulder width	Novel contribution of the present research - visual cues can replace missing proprioceptive shoulder cues
	Action Capabilities	Provide capability to rotate	Confirms real world affordance behavior
Catchability	Evoking Circumstances	Provide objects that indicate detectable height and speed	Confirms real world affordance behavior
	Physical Characteristics	Provide visual and audio cues that indicate self-acceleration and self-speed when objects to catch will land near the critical ratio of 1.2 times the actual catch range	Novel contribution of the present research - visual and auditory cues can replace missing proprioceptive self-acceleration and self-speed cues
	Action Capabilities	Provide capability to move	Confirms real world affordance behavior
Flyability	Evoking Circumstances	Provide objects with vertical and horizontal edges and gaps	Confirms real world affordance behavior
	Physical Characteristics	Provide visual cues that indicate self-height when object to fly over approaches the critical ratio of ½ of the eye point height, and width when the gap to fly through approaches the critical ratio 2.5 gap width to 1.0 shoulder width	Novel contributions of the present research.- 1) identified critical invariant ratios relating body characteristics to action capabilities available only in the VE and 2) visual cues can replace missing proprioceptive cues required for enabling realization of affordances related to action capabilities. available only in the virtual environment
	Action Capabilities	Provide capability to fly	Confirms real world affordance behavior

CHAPTER 6: CONCLUSIONS AND FUTURE RESEARCH

Summary of the Present Research

Virtual Environment interface designs are unique because they aim to present a virtual world, in which users may experience a strong sensation that they are immersed in, or part of, a computer generated world. This "immersiveness," while generally more engaging and vibrant than conventional HCI approaches, brings with it unique design issues. Specifically, VEs aim to present dynamic, multimodal interactions with their represented environment just as the natural environment does. Existing HCI design principles have largely focused on static representations and thus have yet to fully incorporate theories of perception appropriate for the dynamic multimodal interactions inherent to VE interaction. This has led to VE designs whose usability are less than desired, likely because their users cannot readily perceive actions and functions that can and should be enacted. There is thus a need to integrate a comprehensive theory of perception into VE design. Theories of direct perception, in particular affordance theory, may prove particularly relevant to VE system design because affordance theory provides an explanation of the interaction of an organism with its environment. Since VEs intrinsically present an environment, examining how an individual interacts with their surroundings when using a VE should prove particularly interesting and informative. Virtual environment design based on affordance theory could help bridge the gap between what HCI theories provide and VE design needs because affordances purport to explain the communication between objects and observers of an environment. The present research constructs a model of how affordances are realized in the natural world, and how lack of sensory stimuli may lead to realization failures in virtual environments. Specifically, VEs may

lack stimulation of human senses such as vestibular or kinesthetic, and stimuli from the natural world, which are uncorrelated with the intended virtual experience, may intrude and be perceived by the user. The present research proposes that missing sensory stimuli may be successfully replaced by substituted stimuli in modalities actually present, leading to correct perception of affordances.

The present research synthesized from the affordances literature and predicted on the model a set of principles enabling the realization of affordances:

- Affordances depend on objects in the environment.

- Affordances depend on the organism's action capabilities.

- Affordances depend on physical characteristics of the observer.

- Affordances depend on the organism's sources of sensory stimuli.

- Affordances depend on integration of multimodal sensory stimuli.

- Affordances arise as the organism learns to act within its environment.

The model and these principles formed an assertion that could be investigated and from which testable hypotheses could be derived. The research investigated implications of the model and these assertions by considering three affordances: passability, catchability, and flyability. Passability in the real world is indicated by the tendency to rotate when approaching a gap or passageway relatively close to shoulder width. Passability is important because it is fundamental to interaction with static objects in an environment, and as such it directly addresses issues of spatial perception in a virtual environment. Catchability in the real world is the judgment by observers that a moving object can be intercepted in flight. Catchability is important because it is fundamental to interaction with dynamic objects in an environment, and as such catchability involves a temporal component unlike passability, which must be investigated in terms of its realizability in virtual environments. In contrast to passability and catchability, flyability is not a real world affordance. It

125

is the decision to fly in a given set of circumstances as opposed to selecting other forms of locomotion. Flyability is important because it is a fundamental action not available in reality, which VE designers may like to provide to their users, and as such tests the ability of the model to predict how VE users will experience and choose new or unusual capabilities.

The research formulated a set of testable hypotheses based on the conceptual model developed relating to what information would be necessary in the VE to enable the realization of these affordances and how that information could be delivered in the absence of necessary sensory modalities such as vestibular and kinesthetic senses. The research tested the hypotheses through an extensive experimental program. The experimental design involved four factors for each of the three affordances and was implemented as a 2_{IV}^{4-1} fractional factorial design. The four factors related to passability considered were: three visual cues for shoulder width (cueing for physical characteristics) and one cue for passageway width (cueing for object properties). The four factors related to catchability considered were: two visual cues and one audio cue for range (cueing for physical characteristics) and one cue for the object to be caught (cueing for object properties). The four factors related to flyability considered were: two visual cues for size (cueing for physical characteristics) and two cues for window size (cueing for object properties). The experimental apparatus consisted of a series of large rooms implemented in a virtual environment. The cues related to a given affordance were presented in each room as controlled by the experimental design.

The results demonstrated that, as predicted, in the absence of cueing information (i.e., for conventionally designed VEs), the affordances considered were not realized. The predictions for passability and catchability were predicted on existing research, whereas the prediction for flyability was extrapolated from passability and argument. The results demonstrated that for each of the affordances considered when the designed cues for physical characteristics and object properties were provided it led to behavior closely in-line with predicted values. More specifically, when given

affording cues participants tended to rotate their virtual bodies when entering narrow passageways, accurately judge balls as catchable, and fly when conditions warranted it. The results provide a set of preliminary guidelines for VE designers to enable the realization of affordances, which should be further validated through future research.

Findings of the Present Research

The present research has demonstrated three essential findings with explanatory power for enabling the correct perception of affordances in virtual environments.

First, the present research has demonstrated that designed sensory stimuli in available sensory modalities substituted for absent or impoverished modalities in a VE may enable the perception of affordances in VEs with a result comparable to perception of the same affordances in reality. The research has provided potential approaches for designing stimuli; however, the conceptual model and results developed may be criticized as not completely addressing how sensory stimuli are actually processed in the brain. This focus on design of stimuli is herein suggested to be an appropriate approach for the design of virtual environments. First, the only means VE designers have to communicate with users is through design artifacts which become the stimuli in the virtual environment. Second, focusing on design is also fully consistent with the focus of other research in ecological perception. Stoffregen and Riccio (1988) for example argue that the ecological approach to understanding perception is a "black box," where the focus is on the stimuli not on the processing of the stimuli. Future research in this light should focus on substituting sensory stimuli for absent modalities and for affordances not tested in the present study.

Second, the present research has demonstrated potential approaches for enabling the perception of affordances in a VE, which in the real world are cross-modal. The present research focused on cross-modal perception for two reasons. First, circumstances requiring cross-modal

perception have been shown to lead to incorrect perception (Stappers, 1999), and second, most perceptions are in fact cross-modal. Stoffregen and Riccio (1988) state that a great deal of information is only conveyed via cross-modal stimulation, such as that required to walk, sit, and so forth. Future research in this light should focus on confirming the matching of visual stimuli for a wider range of spatial affordances, and on confirming the matching of combined visual/audio stimuli for temporal affordances.

Third, the present research has demonstrated that affordances relating to action capabilities may be enabled by designed sensory stimuli. The criticism may be raised that affordances besides those related to action capabilities are of interest, for example affordances associated with abstract information. However this focus is appropriate for an approach grounded in ecological perception. Flach and Holden (1998) for example describe Gibson (1986) as choosing constraints on action as the fundamental basis for the reality of experience. The conceptual model of the presence research distinguishes between action capability, that is, actions which an organism can attempt, and the limitations of the environment, either real or imagined, that create constraints. Flach and Holden (1998) state "the implication of Gibson's approach for virtual reality is a focus on the coupling between perception and action as the focal point of design." Future research in this light should focus on developing a design approach that integrates cues for multiple affordances.

Future Research

One measure of the value of a research effort is the avenues of pursuit for additional research it opens. The following discussion explores some future research that the present work invites.

The first step would be to confirm the results of this study by testing sensory substitution schemes based on the same approach given the same affordances as well as different affordances. Turvey et al. (1998), for example, argues that objects afford their heaviness to observers. This

affordance would clearly depend on action capabilities in the real world (arm strength), which are not accurately reflected in a virtual environment. The research issues would be "can such an affordance be realized in a virtual environment?", and if so, "what cues enable its realization?" In parallel with this line of investigation, the results of the experiments such studies should be analyzed against the results of the Immersive Tendencies Questionnaire (Witmer & Singer, 1996) and the Motion History Questionnaire (Kennedy & McCauley, 1984), to discover if affordances are enabled and realized differently by identifiable sub-groups of respondents.

The line of future research most complementary to the present research would be to investigate the possibilities offered by the sixth principle synthesized for enabling affordances: "Affordances arise as the organism learns to act within its environment." Marik 1987's experiment suggests that physical characteristics have persistence in the stimulus integration mechanism, and do not simply arise from sensory stimuli. One implication of this, not pursued in the present research, is that a VE could present cueing early in a VE session, which might persist through the experience. In other words, early cueing might eliminate the need for continued cueing.

Another line of inquiry building on the present research would be to consider circumstances that offer multiple affordances simultaneously. Within the sensory substitution scheme adopted here, this would require integrating cues that enable multiple affordances. The failure of the form cue to significantly enable the passability affordance suggests that there may be difficulties with integrating cues may not succeed. The form cue essentially is the bar cue with a neck and simple head mounted on top of it, which apparently confounded the affordance that was present with the simple bar. It is unclear whether the presence of the neck and head afforded something besides passability, or provided a mis-affordance (i.e., contraindication of passability), or simply cluttered the scene too much for the participant to integrate the correct perception. The issue that arises is how

users would be able to integrate many cues in the scene, to enable the realization of a range of affordances.

A desirable research goal in ecological perception is to create a scheme by which the cues enabling perception of any affordance could be realized. The present research has not attempted this, instead focusing on the enabling of three representative affordances. The three affordances selected, passability, catchability, and flyability, are important because they address fundamental functions associated with successful operations in any environment. Furthermore, they deal with three general cases of interest; interaction with static objects in the environment (passability), interaction with dynamic objects in the environment (catchability), and exercise of action capabilities not present in the real world (flyability). Toward a more general scheme for enabling the perception of affordances, the enabling of additional specific affordances that have been documented in the literature could be pursued. Warren's (1984) study, which found phase transition points between walking up stairs and climbing up them on all fours, is another opportunity that could capitalize on the approach adopted in the present research. Likewise Marik's (1987) finding that the affordances of "climb-ability" and "sit-ability" are expressed as constant proportions of leg length suggests that they, like the affordances herein studied, may depend on cross-modal perception and could likewise benefit from this approach. Such studies should confirm that the affordances (heaviness, walk-ability, climb-ability, and sit-ability) are not correctly perceived in ordinary virtual environments, but that additional visual and/or auditory stimuli can enable their correct perception.

The conceptual model for the present research, as captured in Figure 4, was constructed from a synthesis of existing literature on perception of affordances (Marik, 1987; Warren, 1984; Warren & Whang, 1987). This model suggests that affordances are invariantly scaled to physical characteristics and that the sources of such information are missing or impoverished in virtual environments. The present research focuses on providing stimuli that substitute for missing or impoverished stimuli.

130

Consideration of the conceptual model in Figure 4 raises issues beyond sources of stimuli and knowledge of physical characteristics and action capabilities as addressed in the present research. Specifically, the conceptual model asserts that an organism's internal goals and motivation also contribute to enabling the realization of an affordance. The present research does not address the exploitation of knowledge about goals or motivations in enabling the realization of affordances, but imposed a motivation by exploiting a game motif in the instructions to the participants. Future research could investigate how such knowledge is acquired and exploited, and how an organism's behavior regarding such stimuli may provide indication of their goals. For example, Readinger, Chatziastros, Cunningham, Bülthoff, and Cutting (2002) suggest that there may be an invariant relating gaze and direction of travel. Since gaze, unlike shoulder width for example, is a body characteristic that the human controls, if it is invariantly related to behavior (such as the goal or motivation to choose direction of travel), that would suggest a new line of research building on the present work that would reveal knowledge about action capabilities and goals or motivations. This may provide insights on what the human would like afforded at the moment based on their goals and motivation, and could lead to VE interface designs that adapt to their user's desires.

The concept of affordances is so immediately accessible and so plastic that many researchers would like to extend the paradigm beyond perception of reality. De Angeli, Romary, and Wolff (1999), for example, argue that the affordances paradigm can be extended to explain variations in gestures, thereby forming the basis of HCI based on communication by gestures. Since the perception of gestures would involve the perception of one's own gestures through the tactile senses, the present research may offer insights into this pursuit.

Not directly related to developing affordances as a practical VE design technique, the present research has raised questions about the possible utility of HMD versus Screen presentations, which

would also provide a fruitful line of research. Issues such as stereoscopic displays, resolution of displays, and style variants related to presentation media could be investigated.

APPENDIX A: AFFORDANCES IN VIRTUAL ENVIRONMENTS PROTOCOL

<u>**Instructions to experimenter**</u>

This protocol is written as instructions to the experimenter, but includes all instructions to participants.

1. Informed Consent

Basic English language proficiency is required for the informed consent process. If there is any indication that a participant is not English proficient, explore whether or not they do though casual conversation. If you believe that a participant does not have basic English skills, terminate the experiment, and tell the participant that the experiment is complete, and invite them to leave.

Say: "This experiment will involve your exposure to a virtual environment, that is an environment which is created in a computer, and in which you can participate by wearing a head mounted display or viewing a projection screen, and using a computer mouse.

There are risks associated with this experiment. You may experience nausea, vomiting, eyestrain, or dizziness. The risks associated with participation are no greater than those associated with playing any immersive interactive video game or riding an amusement park ride. You can and should terminate the experiment if your discomfort becomes too great. The Institutional Review Board of The Boeing Company has approved this project. An Institutional Review Board approves experiments involving humans when it believes that the risk to the participants is proportional to the possible scientific merit.

This form (show them the informed consent form) explains in detail the risks of this experiment to you, and your rights regarding your participation in this experiment. Please read this carefully. If you choose not to sign, we will dismiss you from the experiment with no consequences to you. If you choose to sign, we will give you a copy of the form for your records.

Wait for their review of the form and consent by signature. Answer any questions they have as fully as possible. If they decide not to sign the form, please ask them politely to leave (consent is required for participation).

2. Pre-exposure Screening

2.1. Simulator Sickness Questionnaire (attached, score of 7.48 or below is required to proceed)
Say: "Please complete this Simulator Sickness Questionnaire, which tells us how you feel today. This data will not be shown with your name to anyone outside of the experimental program. You have the right to refuse to answer any question for any reason."

Do not tell them that a high score will terminate the experiment. When complete, score. They must get a score of 7.48 or below to continue (more than 2 slights or one moderate). If they do not, please ask them politely to leave (satisfactory physical condition is required for participation).

Retain form for additional SSQ scores after exposure in the Virtual Environment.

3. Pre-exposure Baseline Information

If any time, the participant expresses a reluctance to provide information requested on these questionnaires, offer politely to terminate the experiment without prejudice.

3.1. Create Record
Record the participants name on the signed informed disclosure. Enter the participant's number on all surveys. If asked, explain what the number is for, and the protections that will be accorded it.

3.2. Demographics Information (attached)
Say: "Please complete this Demographics Information sheet, which tells us about you. This data will not be shown with your name to anyone outside of the experimental program. You have the right to refuse to answer any question for any reason."

Retain the form when completed.

3.3. Immersive Tendencies Questionnaire (attached)
Say: "Please complete this Immersive Tendencies Questionnaire, which tells us how likely you are to immerse yourself in artificial experiences. This data will not be shown with your name to anyone outside of the experimental program. You have the right to refuse to answer any question for any reason."

Retain the form when completed.

3.4. Motion History Questionnaire (attached)
Say: "Please complete this Motion History Questionnaire, which tells us how much experience you have had with various kinds of unnatural motion. This data will not be shown with your name to anyone outside of the experimental program. You have the right to refuse to answer any question for any reason."

Retain the form when completed.

4. Virtual Environment Orientation
4.1. Accommodation to head mounted display
Say: "Now we're ready to brief you on your exposure to the virtual environment. During exposure, you'll wear this head mounted display (HMD) so it can provide you with visual information about the virtual environment."

Show the participant the HMD and let her or her handle it. Answer any questions.

4.2. Use of computer mouse

During the discussion, Stand and illustrate the explanation of the mouse and movement with your body.

Say: "in order to move about the VE you will use the mouse. If you roll it forward, you will move forward. If you roll it back, you will move back. The further you move it, the faster you go. The left mouse button controls your body rotation. If you click and hold the left button, you will rotate your body to the left; if you release the left button you will return to facing forward. You are limited to a 90-degree rotation. Body rotation does not effect the direction you are facing, or the direction you are traveling. The right mouse button controls your attitude. If you click and hold the right mouse button, you will rise off the ground. If you release the right button, you will return to the earth. You are limited to a height of 2.5 meters off the ground. Flying does not effect the direction you are facing, or the direction you are traveling."

Show the participants the mouse and let them handle it. Answer any questions.

4.3. Tasks to perform in environment
Point to each piece of equipment when named in the explanation.

Say: "The virtual environment you will be experiencing is a prototype of a game, not a complete game. The game involves traveling through virtual rooms and interacting with a virtual ball. We are using this environment to investigate how people perceive information presented in the environment. Do not concern yourself about what information we are investigating, just behave as seems fitting to you.

During your exposure to the virtual world, in the real or physical world, you will remain seated at this desk, looking through the head mounted display or at the projector screen as instructed, and manipulating the mouse. Of course, you can choose to stop the experiment at any time for any reason.

All of the following description is about the virtual world.

During your exposure, you will experience one of three different scenarios in each virtual room. The scenarios are repeated in random order and with slightly varying details. The rooms will be like those in an ordinary large building, 3 meters high, five meters wide, and twenty meters long (9 x 15 x 60 feet) – a large narrow room. When you enter each room, you will see a post or podium in the room, which exists to help keep you oriented. Your overall task is to go through the environment, moving from post to post to post. The post is triangularly shaped, and the higher corner indicates the direction you should go. When you "walk over" the post, the virtual environment will sound a "ding" and briefly "freeze" your position. While you are frozen, the post will sink into the floor. When you leave the room, the post will appear in the next room. There is only one post at any time, so if you see it, it's the right one.

In the first scenario, you will be facing a wall through which is a single passageway exiting the room. Your task is to walk over the post, and then exit the room. As some passageways will be narrow, you may decide you should rotate your virtual body to slip through easily. Use the left mouse button to rotate if you think it appropriate to rotate.

In the second scenario, you will be in a room facing a wall with two exit passageways, and with a ball-throwing machine in the floor near the exits. After you walk over the post, a ball will be tossed at you in such a way as to land in front of or behind you. Your task is to judge whether or not you could have gotten to the ball before it lands in order to catch it. This is not a judgment as to whether or not you have sufficient dexterity to catch it, just a judgment as to whether or not you could have positioned yourself to catch it before it touches the floor. If you like, you can start "moving" so as to catch the ball to improve your judgment. You record your judgment by exiting through the green (left) passageway if you think you could have caught the ball on the fly, or the red (right) passageway if you think you could not have caught it in the air. That's green-left if 'yes', and red-right if 'no'.

In the third scenario, you will be standing in a virtual room, facing a wall through which is a passageway and a window. Your task is to walk over the post and exit the room. To do so, you may decide to walk out the passageway or fly out of the window at your own discretion. Do that which is easiest. Use the right mouse button to fly if you think it appropriate to fly.

If at any time during the exposure, you want to terminate the experiment, simply tell me.

If at any time during the exposure, you are unsure what you are being asked to do, simply ask me.

This is not a time trial. You cannot make any mistakes.

Do you have any questions?" Answer any questions.
-
5. **Virtual Environment Exposure**
   5.1. Entry into environment
Seat the participant and let him or her adjust the chair for comfort. Give him or her the mouse. Help him or her don the helmet.

   5.2. Task Procedure
Start the virtual environment at 800x600x 16 (full screen). Note the participant's number on the survey forms. Monitor the participant's appearance and terminate the experiment if the participant appears ill. Answer any questions raised, and note the questions.

The first room is a training room. Here first help the participant learn to control speed and direction. Then explain the prompting human form used only this is room. Then have the participant use the body rotation and fly mouse buttons. Then have the participant walk over the first post and watch the ball throw. Then have the participant fly over the half-height walls. Then have the participant rotate through the columns. Restart the environment if the participant gets confused or exits the training room. Spend as much time as required for the participant to be comfortable with control movement and position before proceeding. Let them decide when to proceed.

In the passability rooms (single exit), prompt the participant by saying "your task here is to simply to exit cleanly, rotate if you think it would be easier to do so".

In the catchability rooms (two exits, one green, one red), prompt the participant by saying: "Your task here is to judge whether you could have gotten to the ball before it hits the ground to catch it. If you think yes, exit left; if not, exit right."

In the flyability rooms (two exits, one door, one window), prompt the participant by saying "your task is to exit either thru the door or the window, do whichever is easiest".

Monitor the participant for discomfort and terminate the experiment if their discomfort is too great.

6. Post-exposure Tests

6.1. SSQ questionnaires
See paragraph 2.2 and do the same after each exposure, once for the HMD, and once for the projector.

6.2. Cue Survey
Say: "Please complete this Cue Perception Questionnaire, which tells us how much the you notices the cues present, and what you thought their effect was. This data will not be shown with your name to anyone outside of the experimental program. You have the right to refuse to answer any question for any reason."

Retain the form when completed.

Say: "Thank you, the experiment is complete, you can leave if you feel well." If they do not feel well, or their SSQ is significantly above 7.48, ask them to wait 15 minutes in the quiet room.

7. Record Results

Encourage the participant to remain in the lab if they are continuing to experience any unpleasant side effects (nausea, dizziness, etc).

Gather all the paperwork associated with the participant and place in an envelope labeled with the participant's number, and file the envelope in a locked cabinet.

If the experiment is terminated early, change, change their participant number to XX-C, where XX is the original participant number, and "C" is a code indicating the reason for termination:
       E -> early exit by participant
       X -> experimenter error
       C-> computer problem
       O -> Other
Rename the results file to "resultsXX.txt", where XX is the participant's number.

Affordances in Virtual Environments – Informed Consent

Please read this consent document carefully before you decide to participate in this study.

Purpose of the research study: The purpose of this study is to examine how you perceive information presented in virtual environments and how exposure to such environments affects your perception. The results may be used to develop design guidelines for user interfaces.

What you will be asked to do in the study: You will be asked to complete a series baseline tests about your perception and questionnaires describing your general physical condition and prior experience in virtual environments. You will then be asked to wear a helmet-mounted display and use a light hand control. You will be given a short orientation to the virtual environment. The virtual environment consists of rooms like those in an ordinary large building, typically, 3 meters high, five meters wide, and fifteen meters long. You will be asked to attempt a series of simple tasks such as pursuing a ball in the virtual environment. At the conclusion of the tasks, you will be asked to complete a series of tests to assess your re-accommodation to reality.

Time required: One (1) hour or less.

Risks: You may experience nausea, vomiting, eyestrain, or dizziness. These risks are no greater than those associated with playing any immersive interactive video game or riding an amusement park ride. You should terminate the experiment if your discomfort becomes too great. The Institutional Review Board at The Boeing Company has approved this project.

Benefits / Compensation: There is no direct benefit to you for participation. Your time spent on this project is uncompensated and may not be charged to any Boeing project. Your copy of this signed consent form is proof that you have participated.

Confidentiality: Your identity will be kept confidential to the extent provided by law. Your data will be assigned a code number. The list connecting your name to this number will be kept in a locked file in the faculty supervisor's office. The list will be destroyed when the study is completed and the data have been analyzed. Your name will not be used in any report.

Voluntary participation: Your participation in this study is voluntary. There is no penalty for not participating.

Right to withdraw from the study: You will be free to withdraw from the study at any time. There are no hazards or penalties from withdrawing from the study.

Whom to contact if you have questions about the study: The Principal Investigator is David Gross, Associate Technical Fellow, Modeling & Simulation Technology, Phantom Works, (256) 461-3294. The Supervisor is Mr. Bill Tucker, Manager, Modeling & Simulation Technology, Phantom Works, (256) 461-3120.

Payment of Medical Costs. If you are injured during this test, Workers' Compensation will cover your medical costs and applicable time loss. Other Boeing benefit programs you are enrolled in at the time of the test will apply as well.

Your rights in the study: Additional information regarding your rights as a research volunteer may be obtained from:
> J. Michael Muhm
>> Institutional Review Board (IRB) The Boeing Company
>> M/S 7A-XH
>> PO Box 3707
>> Seattle, WA 98142-2207

mike.muhm@boeing.com   Telephone: (425)865-6631
* *

I have read the above information and understand the participation in this research project is voluntary. Refusal to participate, or a decision not to continue to participate, will involve no penalty or loss of benefit to which I am otherwise entitled.

Participant: _____ Date: _____ Participant Number: _____
Investigator: _____ Date: _____

Affordances in Virtual Environments – Demographics Information

1) What is your age? _____ years

2) What is your gender ?   MALE   FEMALE

3) What is your height? _____feet ____ inches

4) Are you color blind ? NO   YES   If so, what type? _____

5) Is there any reason you can not work around TV/Radio signals?
   NO   YES   If so, Why? _____

6) Do you have normal vision?
   NO   YES   If so, skip to question 8

7) Is your vision corrected by …
   GLASSES   CONTACTS   NOT-CORRECTED

8) If corrected, are you using it now ?
   YES   NO   If not, why not? _____

9) Do you have any other unusual vision conditions?
   NO   YES   If so, what? _____

10) Do you have normal hearing?   NO   YES   If so, skip to question 14

11) Is your hearing … CORRECTED   NOT-CORRECTED

12) Are you wearing your hearing correction?
    YES   NO   If not, why not? _____

13) Do you have any other unusual hearing conditions?
    NO   YES   If so, what? _____

14) I am [RIGHT | LEFT | AMBIDEXTROUS] handed (circle one).

Affordances in Virtual Environments – Cue Perception Questionnaire

The virtual rooms presented three scenarios. Each scenario was repeated a number of times, with slightly varying details, or cues. This survey is to discover what you remember about the cues and how you think that they affected your behavior in the environment. Please complete the following tables.

Passability -- room with single passageway exit

Why did you decide you should rotate, if you did? _____
_____

Cues Noticed	Perceived Effect

Catchability -- room with two passageway exits, and ball thrown

Why did you decide you could catch it, if you did? _____
_____

Cues Noticed	Perceived Effect

Flyability – rooms with single passageway and single window exits

Why did you decide you should fly, if you did? _____
_____

Cues Noticed	Perceived Effect

APPENDIX B: ANALYSIS OF PARTICIPANT SURVEY RESPONSES

Participants were asked to complete version 3.01 of the Immersive Tendencies Questionnaire (Witmer & Singer, 1996)

.In general, the higher the answer, the more likely is a participant to suspend disbelief and immerse himself in the experience. Figure B-1 shows the mean response for each participant group with error bars indicating the 95% confidence intervals. By inspection, it can be sent that the confidence intervals overlap, which indicates that no statistically significant difference was found with regard to these factors between the various participant groups.
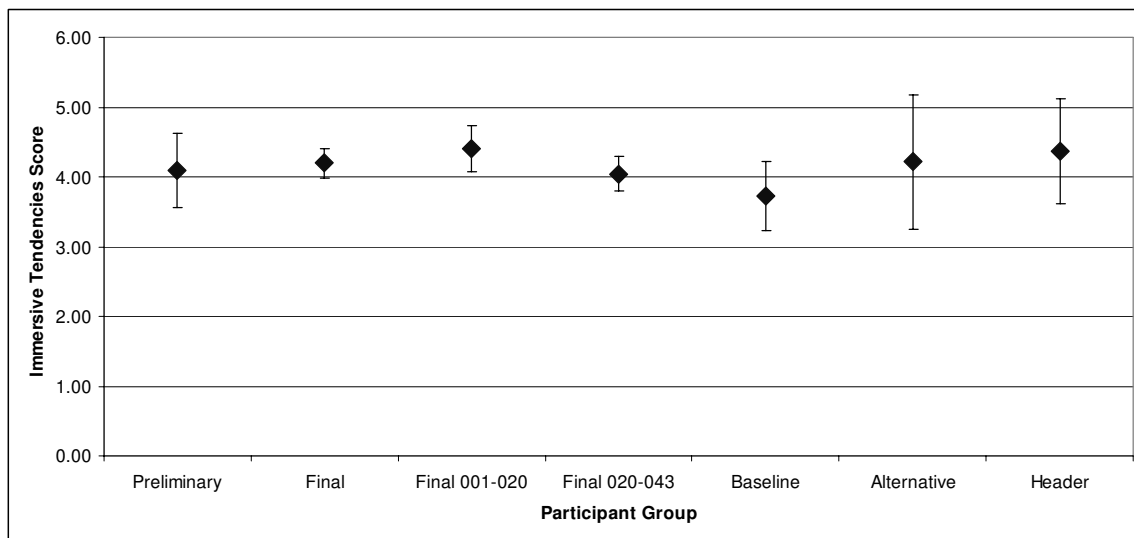
Figure B-1: Immersive tendencies questionnaire average response per group.

Participants were asked to complete a Motion History Questionnaire developed by Kennedy and McCauley (1984). Three questions are particularly revealing about the likelihood that a participant would experience simulator sickness in the VE: "2) How often would you say you get airsick?"; "4) From your experience at sea, how often would you say you get seasick?"; and "7) In general, how susceptible to motion sickness are you?" The first two questions provide responses: Always, Frequently, Sometimes, Rarely, and Never; the last provides: Extremely, Very, Moderately, Minimally, and Not at all. To better support analysis, the participant's responses were converted into numbers one through five, where one was assigned to the first response and five was assigned

143

to the last. Therefore, higher numerical scores indicate that the participant experienced these symptoms less. Figure B-2 summarizes the results for these three questions for each participant groups with error bars indicating the 95% confidence intervals. By inspection, it can be sent that the confidence intervals overlap, which indicates that no statistically significant difference was found with regard to these factors between the various participant groups.
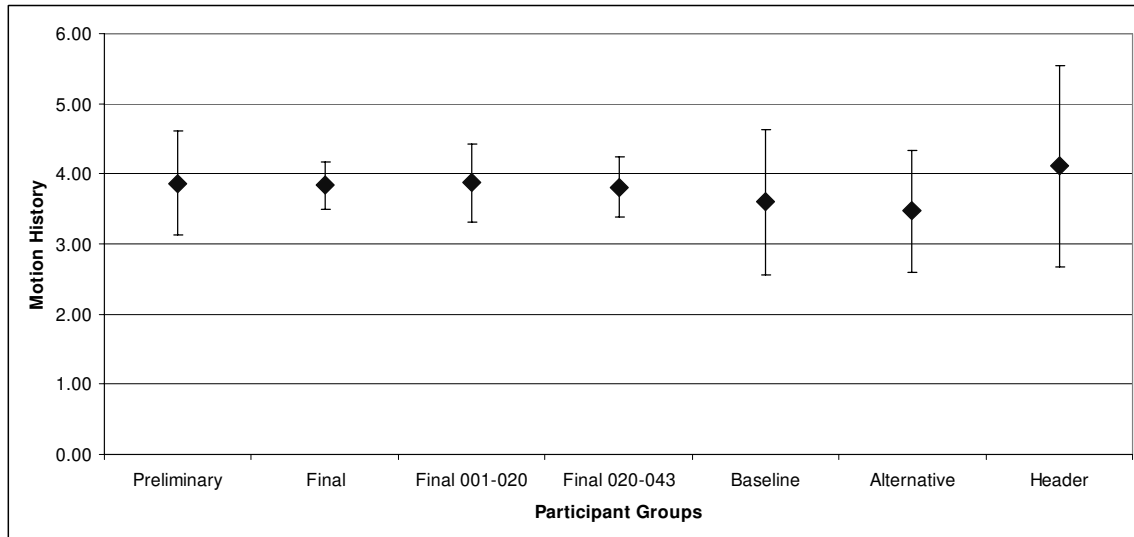
Figure B-2: Motion history average response per group.

Participants completed a Simulator Sickness Questionnaire (SSQ) developed by Kennedy et al. (1993) before any exposure to the VE, after the first exposure, and after the second (as appropriate). As discussed in the Experiment Design, some participants were exposed to the VE first via a HMD, and sometimes first via a computer projector Screen. These reversed in the second exposure. These scores served as a way to judge that a participant was not experiencing too much discomfort to continue the experiment. Any SSQ score above 7.48 resulted in an invitation to terminate the experiment. As noted, five participants chose to terminate. Figure B-3 illustrates the SSQ scores for the final study participant group with error bars indicating the 95% confidence intervals. By inspection, the confidence intervals indicate that there are statistically significant differences between some of the subgroups. The first-exposure-via-HMD subgroup is significantly different that the

144

second-exposure-via Screen. This indicates that the participants recovered from discomfort during their exposure to the Screen. Also, the second-exposure-via-HMD subgroup is significantly different than the second-exposure-via-screen. This indicates that the HMD exposure created significantly more discomfort than the Screen exposure.
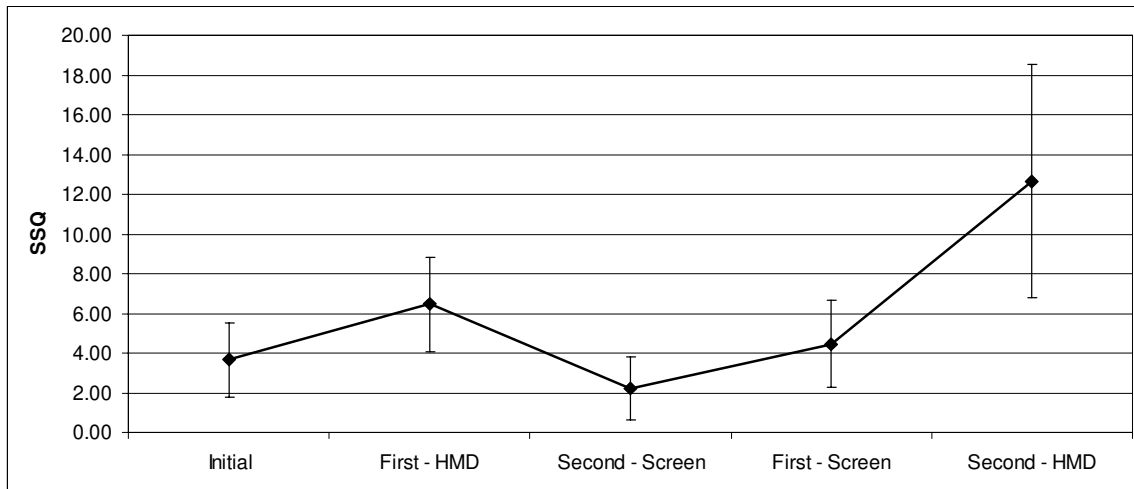
Figure B-3: Simulator sickness scores for the final study participant group.

APPENDIX C: RESPONSES MEASURED IN THE VIRTUAL ENVIRONMENT

Example Raw Data – F001-H

Room	X	Y	Z	Rotate	Speed
0	-4250	60	-100	0	0
0	-4250	60	-100	0	0
0	-4250	60	-100	0	0
0	-4250	60	-100	0	0
0	-4250	60	-100	0	0
0	-4250	60	-100	0	0
0	-4250	60	-100	0	0
0	-4250	60	-100	0	0
0	-4250	60	-100	0	0
0	-4250	60	-100	0	0
0	-4250	60	-100	0	0
0	-4250	60	-100	0	0
0	-4250	60	-100	0	0
0	-4250	60	-100	0	0
0	-4249.273	60	-100.7161	0	60.000004
0	-4248.59	60	-101.3902	0	60.000004
0	-4247.864	60	-102.1064	0	60.000004
0	-4247.18	60	-102.7805	0	60.000004
0	-4246.454	60	-103.4967	0	60.000004
0	-4245.77	60	-104.1707	0	60.000004
0	-4245.044	60	-104.8869	0	60.000004
0	-4244.318	60	-105.6031	0	60.000004
0	-4243.635	60	-106.2772	0	60.000004
0	-4242.909	60	-106.9934	0	60.000004
0	-4242.225	60	-107.6674	0	60.000004
0	-4241.499	60	-108.3836	0	60.000004
0	-4240.773	60	-109.0998	0	60.000004
0	-4240.089	60	-109.7739	0	60.000004
0	-4239.363	60	-110.4901	0	60.000004
0	-4238.68	60	-111.1642	0	60.000004
0	-4237.954	60	-111.8803	0	60.000004
0	-4237.228	60	-112.5965	0	60.000004
0	-4236.544	60	-113.2706	0	60.000004
0	-4235.818	60	-113.9868	0	60.000004
0	-4235.134	60	-114.6609	0	60.000004
0	-4234.408	60	-115.3771	0	60.000004
0	-4233.682	60	-116.0933	0	60.000004
0	-4232.999	60	-116.7673	0	60.000004
0	-4232.272	60	-117.4835	0	60.000004
0	-4231.589	60	-118.1576	0	60.000004
0	-4230.863	60	-118.8738	0	60.000004
0	-4230.137	60	-119.59	0	60.000004
0	-4229.453	60	-120.264	0	60.000004
0	-4228.727	60	-120.9802	0	60.000004
0	-4228.043	60	-121.6543	0	60.000004
0	-4227.317	60	-122.3705	0	60.000004
0	-4226.591	60	-123.0867	0	60.000004
0	-4225.908	60	-123.7607	0	60.000004
0	-4225.182	60	-124.4769	0	60.000004
0	-4224.498	60	-125.151	0	60.000004
0	-4223.772	60	-125.8672	0	60.000004
0	-4223.041	60	-126.5783	0	60.000004
0	-4222.352	60	-127.2476	0	60.000004
0	-4221.621	60	-127.9587	0	60.000004
0	-4220.924	60	-128.6265	0	60.300003
0	-4220.185	60	-129.336	0	60.300003
0	-4219.445	60	-130.0455	0	60.300003

147

Room	X	Y	Z	Rotate	Speed
0	-4218.749	60	-130.7133	0	60.300003
0	-4218.009	60	-131.4228	0	60.300003
0	-4217.312	60	-132.0906	0	60.300003
0	-4216.573	60	-132.8001	0	60.300003
0	-4215.824	60	-133.5079	0	60.600002
0	-4215.12	60	-134.1741	0	60.600002
0	-4214.371	60	-134.882	0	60.600002
0	-4213.71	60	-135.5065	0	60.600002
0	-4212.962	60	-136.2144	0	60.600002
0	-4212.213	60	-136.9222	0	60.600002
0	-4211.509	60	-137.5884	0	60.600002
0	-4210.76	60	-138.2963	0	60.600002
0	-4210.056	60	-138.9625	0	60.600002
0	-4209.298	60	-139.6685	0	60.900002
0	-4208.541	60	-140.3746	0	60.900002
0	-4207.829	60	-141.0391	0	60.900002
0	-4207.071	60	-141.7452	0	60.900002
0	-4206.341	60	-142.3979	0	61.200001
0	-4205.557	60	-143.0893	0	61.500004
0	-4204.773	60	-143.7807	0	61.500004
0	-4204.03	60	-144.4263	0	61.500004
0	-4203.241	60	-145.1122	0	61.500004
0	-4202.499	60	-145.7577	0	61.500004
0	-4201.709	60	-146.4436	0	61.500004
0	-4200.92	60	-147.1296	0	61.500004
0	-4200.178	60	-147.7751	0	61.500004
0	-4199.389	60	-148.461	0	61.500004
0	-4198.6	60	-149.147	0	61.500004
0	-4197.857	60	-149.7925	0	61.500004
0	-4197.068	60	-150.4784	0	61.500004
0	-4196.325	60	-151.124	0	61.500004
0	-4195.536	60	-151.8099	0	61.500004
0	-4194.747	60	-152.4958	0	61.500004
0	-4194.004	60	-153.1414	0	61.500004
0	-4193.215	60	-153.8273	0	61.500004
0	-4192.473	60	-154.4729	0	61.500004
0	-4191.684	60	-155.1588	0	61.500004
0	-4190.895	60	-155.8447	0	61.500004
0	-4190.152	60	-156.4903	0	61.500004
0	-4189.363	60	-157.1762	0	61.500004
0	-4188.62	60	-157.8218	0	61.500004
0	-4187.831	60	-158.5077	0	61.500004
0	-4187.042	60	-159.1936	0	61.500004
0	-4186.299	60	-159.8392	0	61.500004

… and so forth.

Task Room 1 Reduced Data

File	Room	X	Y	Z	Rotate	Speed	RESULT
A001-H	1	-3071.000	60.000	-81.081	90.0	57.3	ROTATE
A002-H	1	-3071.459	60.000	-80.362	90.0	43.2	ROTATE
A003-H	1	-3071.003	60.000	-84.281	0.0	55.8	no
A004-H	1	-3070.871	60.000	-84.490	0.0	49.5	no
A005-H	1	-3071.133	60.000	-86.811	0.0	62.7	no
B001-H	1	-3070.953	60.000	-114.390	0.0	14.7	no
B001-S	1	-3070.966	60.000	-85.079	90.0	25.8	ROTATE
B002-H	1	-3070.804	60.000	-106.965	90.0	30.3	ROTATE

B002-S	1	-3071.583	60.000	-85.093	0.0	68.1	no
B003-H	1	-3071.153	60.000	-111.164	0.0	30.0	no
B003-S	1	-3070.777	60.000	-82.724	0.0	54.6	no
B004-H	1	-3071.051	60.000	-106.591	57.0	83.1	ROTATE
B004-S	1	-3071.716	60.000	-84.853	0.0	57.6	no
B005-H	1	-3070.907	60.000	-98.701	90.0	41.4	ROTATE
B005-S	1	-3071.610	60.000	-86.005	0.0	53.4	no
F001-H	1	-3070.929	60.000	-91.078	0.0	13.5	no
F001-S	1	-3070.914	60.000	-78.933	90.0	36.9	ROTATE
F002-H	1	-3071.595	60.000	-103.855	0.0	64.5	no
F002-S	1	-3071.627	60.000	-80.926	0.0	62.7	no
F003-H	1	-3071.288	60.000	-95.679	90.0	40.8	ROTATE
F003-S	1	-3071.551	60.000	-83.763	0.0	147.9	no
F004-H	1	-3070.979	60.000	-86.850	0.0	67.8	no
F004-S	1	-3071.042	60.000	-86.530	0.0	39.3	no
F005-H	1	-3071.590	60.000	-91.303	0.0	52.8	no
F005-S	1	-3071.638	60.000	-85.981	0.0	73.5	no
F006-H	1	-3071.252	60.000	-86.845	90.0	67.5	ROTATE
F006-S	1	-3070.774	60.000	-81.888	0.0	35.7	no
F007-H	1	-3071.448	60.000	-95.617	90.0	48.6	ROTATE
F007-S	1	-3070.955	60.000	-86.136	0.0	88.8	no
F008-H	1	-3070.794	60.000	-83.274	0.0	27.3	no
F008-S	1	-3071.135	60.000	-84.745	0.0	43.5	no
F009-H	1	-3071.683	60.000	-96.824	90.0	60.9	ROTATE
F009-S	1	-3072.637	60.000	-78.077	0.0	150.0	no
F010-H	1	-3070.979	64.000	-105.898	0.0	81.9	m/b
F010-S	1	-3070.827	60.000	-82.993	0.0	29.1	no
F011-H	1	-3070.967	60.000	-90.876	0.0	32.1	no
F011-S	1	-3070.868	60.000	-85.696	0.0	37.8	no
F012-H	1	-3071.380	60.000	-82.700	0.0	72.6	no
F012-S	1	-3071.164	60.000	-83.302	0.0	44.1	no
F013-H	1	-3071.164	60.000	-96.101	0.0	47.4	no
F013-S	1	-3072.235	60.000	-78.352	0.0	111.0	no
F014-H	1	-3071.087	60.000	-87.724	0.0	33.0	no
F014-S	1	-3070.876	60.000	-85.890	0.0	31.5	no
F015-H	1	-3071.270	60.000	-89.133	0.0	36.0	no
F015-S	1	-3070.757	60.000	-85.435	0.0	56.7	no
F016-H	1	-3070.902	60.000	-92.297	90.0	9.9	ROTATE
F016-S	1	-3071.418	60.000	-82.256	90.0	42.9	ROTATE
F017-H	1	-3071.216	60.000	-106.410	24.0	45.0	ROTATE
F017-S	1	-3071.329	60.000	-83.809	0.0	42.9	no
F018-H	1	-3071.447	60.000	-96.132	0.0	54.9	no
F018-S	1	-3071.424	60.000	-85.801	0.0	41.4	no
F019-H	1	-3070.948	60.000	-94.199	0.0	15.6	no
F019-S	1	-3071.799	60.000	-84.793	0.0	93.3	no
F020-H	1	-3070.849	60.000	-90.480	0.0	45.3	no
F020-S	1	-3071.068	60.000	-83.115	0.0	34.5	no
F021-H	1	-3071.219	60.000	-93.222	0.0	34.5	no
F021-S	1	-3071.439	60.000	-82.494	0.0	54.6	no
F022-H	1	-3071.064	60.000	-83.019	0.0	72.9	no
F022-S	1	-3071.156	60.000	-85.172	0.0	51.6	no
F023-H	1	-3071.126	60.000	-95.289	0.0	61.8	no
F023-S	1	-3071.422	60.000	-87.706	0.0	70.2	no
F024-H	1	-3070.882	60.000	-100.093	90.0	50.4	ROTATE
F024-S	1	-3070.756	60.000	-87.198	0.0	43.2	no
F025-H	1	-3071.422	60.000	-89.629	0.0	59.7	no
F025-S	1	-3071.686	60.000	-84.150	0.0	59.4	no
F026-H	1	-3071.026	60.000	-83.851	0.0	57.6	no
F026-S	1	-3071.115	60.000	-83.745	0.0	35.7	no
F027-H	1	-3071.439	60.000	-93.707	0.0	53.4	no

File	Room	X	Y	Z	Rotate	Speed	RESULT
F027-S	1	-3070.940	60.000	-84.082	0.0	89.4	no
F028-H	1	-3071.431	60.000	-93.411	0.0	40.8	no
F028-S	1	-3070.808	60.000	-87.282	0.0	33.6	no
F029-H	1	-3071.114	60.000	-87.205	0.0	46.2	no
F029-S	1	-3071.249	60.000	-81.952	0.0	39.0	no
F030-H	1	-3071.118	60.000	-87.484	0.0	46.8	no
F030-S	1	-3071.000	60.000	-87.166	0.0	37.8	no
F031-H	1	-3071.228	60.000	-87.633	0.0	29.1	no
F031-S	1	-3071.768	60.000	-81.260	0.0	68.7	no
F032-H	1	-3070.858	60.000	-95.953	90.0	59.1	ROTATE
F032-S	1	-3071.055	60.000	-84.563	0.0	44.7	no
F033-H	1	-3071.611	60.000	-88.753	0.0	63.6	no
F033-S	1	-3073.043	60.000	-80.069	0.0	150.0	no
F034-H	1	-3071.508	60.000	-108.905	0.0	76.2	no
F034-S	1	-3071.367	60.000	-82.766	0.0	41.7	no
F035-H	1	-3071.206	60.000	-96.182	90.0	39.6	ROTATE
F035-S	1	-3071.345	60.000	-81.319	57.0	42.3	ROTATE
F036-H	1	-3071.063	60.000	-81.062	0.0	37.2	no
F036-S	1	-3071.207	60.000	-80.863	90.0	35.7	ROTATE
F037-H	1	-3070.934	60.000	-98.488	0.0	60.9	no
F037-S	1	-3070.960	60.000	-84.916	0.0	18.9	no
F038-H	1	-3070.760	60.000	-100.955	90.0	46.5	ROTATE
F038-S	1	-3070.983	60.000	-90.925	0.0	45.0	no
F040-H	1	-3070.858	60.000	-86.705	0.0	38.7	no
F040-S	1	-3071.267	60.000	-80.610	0.0	37.8	no
F041-H	1	-3070.859	60.000	-90.254	0.0	26.4	no
F041-S	1	-3071.041	60.000	-86.369	0.0	65.4	no
F042-H	1	-3071.327	60.000	-93.035	0.0	62.4	no
F042-S	1	-3071.447	60.000	-86.713	0.0	42.3	no
F043-H	1	-3070.908	60.000	-94.148	66.0	34.2	ROTATE
F043-S	1	-3071.018	60.000	-87.004	0.0	24.6	no
H001-H	1	-3071.099	60.000	-79.252	0.0	26.1	no
H002-H	1	-3071.072	60.000	-95.445	0.0	32.7	no
H003-H	1	-3071.011	60.000	-94.641	90.0	36.6	ROTATE
I001-H	1	-3071.835	60.000	-95.328	0.0	68.7	no
I001-S	1	-3071.272	60.000	-88.647	0.0	51.0	no
P001-H	1	-3071.425	60.000	-97.754	90.0	68.7	ROTATE
P001-S	1	-3071.498	60.000	-86.164	0.0	60.3	no
P002-H	1	-3071.658	60.000	-104.426	90.0	68.1	ROTATE
P002-S	1	-3070.806	60.000	-84.955	0.0	22.8	no
P003-H	1	-3070.841	60.000	-101.840	90.0	20.1	ROTATE
P003-S	1	-3070.813	60.000	-87.201	0.0	25.2	no
P004-H	1	-3071.060	60.000	-85.176	0.0	47.1	no
P004-S	1	-3072.440	136.000	-90.986	0.0	101.1	m/b
P005-H	1	-3070.908	60.000	-90.168	0.0	18.9	no
P005-S	1	-3070.780	60.000	-81.778	90.0	21.3	ROTATE
P006-H	1	-3071.016	60.000	-79.311	0.0	58.2	no
P006-S	1	-3070.762	60.000	-84.792	0.0	29.4	no
P007-H	1	-3070.808	60.000	-100.563	0.0	41.7	no
P007-S	1	-3070.997	60.000	-84.655	0.0	17.1	no
P008-H	1	-3071.012	60.000	-100.767	0.0	81.6	no
P008-S	1	-3071.069	60.000	-103.670	0.0	48.3	no
P009-H	1	-3070.825	60.000	-86.863	0.0	40.5	no
P009-S	1	-3072.304	60.000	-82.433	0.0	115.5	no
P010-H	1	-3070.788	60.000	-107.432	0.0	61.2	no
P010-S	1	-3071.233	60.000	-105.804	0.0	38.1	no

Task Room 2 Reduced Data

File	Room	X	Y	Z	Rotate	Speed	RESULT

A001-H	2	-3019.634	60.000	-563.931	66.0	49.2	CATCH
A002-H	2	-2887.812	60.000	-564.464	0.0	33.6	not
A003-H	2	-3007.439	60.000	-564.352	0.0	28.5	CATCH
A004-H	2	-2991.539	60.000	-564.451	0.0	37.5	CATCH
A005-H	2	-2884.837	60.000	-564.261	0.0	40.2	not
B001-H	2	-2981.951	60.000	-564.382	0.0	17.4	CATCH
B001-S	2	-2881.020	60.000	-564.425	0.0	16.8	not
B002-H	2	-2878.880	60.000	-564.279	0.0	33.0	not
B002-S	2	-2876.673	60.000	-564.264	0.0	58.2	not
B003-H	2	-3008.604	60.000	-564.400	0.0	30.0	CATCH
B003-S	2	-2881.942	60.000	-563.992	0.0	44.7	not
B004-H	2	-2995.579	60.000	-563.587	0.0	58.5	CATCH
B004-S	2	-2877.098	60.000	-564.000	0.0	67.2	not
B005-H	2	-2999.796	60.000	-564.185	0.0	54.6	CATCH
B005-S	2	-2882.957	60.000	-564.459	0.0	9.6	not
F001-H	2	-2885.458	60.000	-564.262	0.0	16.2	not
F001-S	2	-2874.737	60.000	-564.018	0.0	37.5	not
F002-H	2	-2884.100	60.000	-564.127	0.0	68.7	not
F002-S	2	-3002.272	60.000	-564.448	0.0	34.8	CATCH
F003-H	2	-2890.297	60.000	-564.103	0.0	33.9	not
F003-S	2	-2995.246	60.000	-563.697	0.0	87.3	CATCH
F004-H	2	-2981.940	60.000	-564.458	0.0	80.7	CATCH
F004-S	2	-2880.810	60.000	-564.275	0.0	30.3	not
F005-H	2	-2879.353	60.000	-564.185	0.0	33.9	not
F005-S	2	-2888.091	60.000	-563.558	0.0	58.5	not
F006-H	2	-3000.766	60.000	-563.711	0.0	79.5	CATCH
F006-S	2	-2877.555	60.000	-564.122	0.0	61.2	not
F007-H	2	-2884.562	60.000	-563.831	0.0	44.4	not
F007-S	2	-2882.359	60.000	-564.356	90.0	56.4	not
F008-H	2	-2887.296	60.000	-564.176	0.0	42.0	not
F008-S	2	-2886.631	60.000	-564.237	0.0	34.8	not
F009-H	2	-2877.375	60.000	-564.312	84.0	44.1	not
F009-S	2	-2874.459	60.000	-562.635	48.0	135.3	not
F010-H	2	-2877.075	60.000	-564.333	0.0	66.9	not
F010-S	2	-2884.455	60.000	-564.007	0.0	40.8	not
F011-H	2	-2887.296	60.000	-564.269	0.0	26.7	not
F011-S	2	-2884.466	60.000	-564.154	0.0	39.9	not
F012-H	2	-2884.323	60.000	-563.594	0.0	72.0	not
F012-S	2	-2885.062	60.000	-564.079	0.0	27.0	not
F013-H	2	-2881.490	60.000	-564.008	0.0	45.9	not
F013-S	2	-2874.495	60.000	-563.190	0.0	108.3	not
F014-H	2	-2887.286	60.000	-564.090	0.0	41.4	not
F014-S	2	-2885.853	60.000	-564.461	0.0	23.1	not
F015-H	2	-2897.524	60.000	-564.080	0.0	60.0	not
F015-S	2	-2875.742	60.000	-564.094	0.0	62.4	not
F016-H	2	-2885.333	60.000	-564.482	0.0	11.7	not
F016-S	2	-2879.488	60.000	-564.380	90.0	30.6	not
F017-H	2	-2882.614	60.000	-563.868	0.0	40.2	not
F017-S	2	-2876.606	60.000	-564.157	0.0	43.8	not
F018-H	2	-2888.114	60.000	-564.098	0.0	44.4	not
F018-S	2	-2883.883	60.000	-564.370	0.0	23.1	not
F019-H	2	-3004.656	60.000	-564.136	0.0	26.7	CATCH
F019-S	2	-2875.900	60.000	-564.053	0.0	74.1	not
F020-H	2	-2892.533	60.000	-564.499	0.0	49.5	not
F020-S	2	-3001.733	60.000	-564.323	0.0	21.3	CATCH
F021-H	2	-2887.922	60.000	-564.478	0.0	22.5	not
F021-S	2	-2875.337	60.000	-564.075	0.0	89.7	not
F022-H	2	-2886.123	60.000	-563.804	0.0	73.2	not
F022-S	2	-2882.266	60.000	-564.159	0.0	45.0	not
F023-H	2	-2881.015	60.000	-564.416	0.0	68.7	not

F023-S	2	-2874.410	60.000	-564.341	0.0	77.7	not
F024-H	2	-2880.746	60.000	-564.447	0.0	32.4	not
F024-S	2	-2881.162	60.000	-564.419	0.0	31.2	not
F025-H	2	-2880.994	60.000	-564.494	0.0	47.7	not
F025-S	2	-2874.422	60.000	-563.575	0.0	63.6	not
F026-H	2	-2882.832	60.000	-563.586	0.0	63.0	not
F026-S	2	-2885.159	60.000	-564.299	0.0	26.7	not
F027-H	2	-2881.721	60.000	-563.931	0.0	58.8	not
F027-S	2	-2879.257	60.000	-563.949	0.0	95.4	not
F028-H	2	-2891.834	60.000	-564.111	0.0	26.4	not
F028-S	2	-2883.709	60.000	-564.467	0.0	23.4	not
F029-H	2	-2890.550	60.000	-564.227	0.0	29.7	not
F029-S	2	-3004.680	60.000	-564.383	0.0	40.8	CATCH
F030-H	2	-2886.238	60.000	-564.064	0.0	53.7	not
F030-S	2	-2879.870	60.000	-564.021	0.0	33.0	not
F031-H	2	-2885.825	60.000	-564.488	0.0	31.8	not
F031-S	2	-2878.282	60.000	-564.030	0.0	70.8	not
F032-H	2	-2887.546	60.000	-564.425	0.0	81.9	not
F032-S	2	-2882.526	60.000	-564.384	0.0	46.5	not
F033-H	2	-2880.047	60.000	-564.293	0.0	58.5	not
F033-S	2	-2882.011	60.000	-563.581	0.0	115.2	not
F034-H	2	-2886.385	60.000	-563.270	0.0	83.1	not
F034-S	2	-2880.845	60.000	-564.090	0.0	45.3	not
F035-H	2	-2882.404	60.000	-564.201	90.0	35.1	not
F035-S	2	-2878.984	60.000	-564.340	0.0	40.5	not
F036-H	2	-2883.227	60.000	-564.292	0.0	29.4	not
F036-S	2	-2890.059	60.000	-564.387	0.0	13.2	not
F037-H	2	-3008.613	60.000	-563.633	0.0	67.2	CATCH
F037-S	2	-2879.053	60.000	-563.770	0.0	79.5	not
F038-H	2	-2876.731	60.000	-563.903	0.0	45.9	not
F038-S	2	-2874.414	60.000	-564.017	0.0	48.0	not
F040-H	2	-2891.491	60.000	-564.184	0.0	34.8	not
F040-S	2	-2880.484	60.000	-564.105	0.0	24.3	not
F041-H	2	-3003.748	60.000	-564.011	0.0	40.5	CATCH
F041-S	2	-2991.265	60.000	-563.988	0.0	42.3	CATCH
F042-H	2	-2884.614	60.000	-564.118	0.0	44.4	not
F042-S	2	-2885.588	60.000	-564.103	0.0	36.0	not
F043-H	2	-2880.299	60.000	-564.484	0.0	15.9	not
F043-S	2	-2886.387	60.000	-564.158	0.0	31.2	not
H001-H	2	-2881.996	60.000	-564.233	0.0	38.7	not
H002-H	2	-2890.044	60.000	-564.408	0.0	18.0	not
H003-H	2	-2886.688	60.000	-564.497	0.0	35.1	not
I001-H	2	-2874.426	60.000	-563.942	0.0	75.9	not
I001-S	2	-2878.691	60.000	-563.992	0.0	36.0	not
P001-H	2	-2885.519	60.000	-563.906	90.0	55.5	not
P001-S	2	-2882.365	60.000	-563.852	0.0	61.8	not
P002-H	2	-2886.648	60.000	-563.554	0.0	68.1	not
P002-S	2	-2881.028	60.000	-564.183	0.0	26.1	not
P003-H	2	-2885.083	60.000	-564.349	0.0	12.9	not
P003-S	2	-2874.413	60.000	-564.184	0.0	21.9	not
P004-H	2	-2874.427	60.000	-563.807	0.0	58.8	not
P004-S	2	-2901.585	60.000	-564.378	0.0	23.1	not
P005-H	2	-2886.392	60.000	-564.445	0.0	23.1	not
P005-S	2	-2882.956	60.000	-564.078	0.0	43.5	not
P006-H	2	-2888.980	60.000	-564.124	0.0	47.4	not
P006-S	2	-2883.509	60.000	-564.182	0.0	21.9	not
P007-H	2	-2883.679	60.000	-564.339	0.0	25.8	not
P007-S	2	-2879.194	60.000	-564.439	0.0	19.2	not
P008-H	2	-2874.478	60.000	-563.916	0.0	63.6	not
P008-S	2	-2886.240	60.000	-564.250	0.0	28.5	not

File	Room	X	Y	Z	Rotate	Speed	RESULT
P009-H	2	-2887.007	60.000	-563.922	0.0	50.7	not
P009-S	2	-2890.017	60.000	-563.926	0.0	69.9	not
P010-H	2	-2874.462	60.000	-563.986	0.0	45.3	not
P010-S	2	-2874.519	60.000	-564.478	0.0	29.1	not

Task Room 3 Reduced Data

File	Room	X	Y	Z	Rotate	Speed	RESULT
A001-H	3	-2481.859	60.000	-617.434	0.0	45.9	no
A002-H	3	-2481.833	60.000	-616.409	0.0	35.7	no
A003-H	3	-2481.590	60.000	-620.698	0.0	23.7	no
A004-H	3	-2481.670	125.000	-713.014	0.0	30.6	FLY
A005-H	3	-2481.482	125.000	-707.317	0.0	51.0	FLY
B001-H	3	-2481.308	60.000	-633.516	0.0	12.3	no
B001-S	3	-2481.400	60.000	-617.711	0.0	17.4	no
B002-H	3	-2481.391	60.000	-626.449	0.0	27.0	no
B002-S	3	-2482.080	60.000	-619.862	0.0	52.8	no
B003-H	3	-2481.685	125.000	-722.857	0.0	30.0	FLY
B003-S	3	-2482.239	60.000	-607.570	0.0	62.7	no
B004-H	3	-2482.141	125.000	-720.901	0.0	64.8	FLY
B004-S	3	-2481.402	60.000	-628.207	0.0	82.5	no
B005-H	3	-2481.684	60.000	-635.357	90.0	27.9	m/b
B005-S	3	-2481.321	60.000	-622.831	0.0	18.9	no
F001-H	3	-2481.475	121.000	-713.204	0.0	24.3	FLY
F001-S	3	-2481.815	125.000	-724.199	0.0	41.1	FLY
F002-H	3	-2481.606	125.000	-712.122	0.0	69.6	FLY
F002-S	3	-2481.780	125.000	-724.420	0.0	70.5	FLY
F003-H	3	-2481.972	125.000	-713.206	0.0	48.9	FLY
F003-S	3	-2482.312	125.000	-715.090	0.0	110.7	FLY
F004-H	3	-2482.092	73.000	-721.118	0.0	56.7	FLY
F004-S	3	-2482.211	125.000	-725.267	0.0	63.3	FLY
F005-H	3	-2481.948	125.000	-714.444	0.0	140.4	FLY
F005-S	3	-2482.187	125.000	-712.131	0.0	108.6	FLY
F006-H	3	-2481.867	60.000	-623.584	0.0	53.4	no
F006-S	3	-2481.668	125.000	-721.459	0.0	68.4	FLY
F007-H	3	-2481.607	60.000	-618.555	0.0	37.2	no
F007-S	3	-2481.938	60.000	-612.351	90.0	43.2	m/b
F008-H	3	-2481.515	125.000	-712.799	0.0	34.2	FLY
F008-S	3	-2481.626	125.000	-710.871	0.0	37.8	FLY
F009-H	3	-2481.381	125.000	-716.496	0.0	46.2	FLY
F009-S	3	-2482.479	60.000	-612.918	45.0	148.5	m/b
F010-H	3	-2481.304	125.000	-717.510	0.0	62.7	FLY
F010-S	3	-2481.458	60.000	-624.766	0.0	22.2	no
F011-H	3	-2481.858	60.000	-630.953	0.0	41.1	no
F011-S	3	-2481.408	60.000	-633.098	0.0	28.5	no
F012-H	3	-2481.353	60.000	-612.608	0.0	60.6	no
F012-S	3	-2481.404	60.000	-619.104	0.0	38.7	no
F013-H	3	-2481.716	60.000	-624.480	0.0	56.4	no
F013-S	3	-2482.635	60.000	-613.317	0.0	99.3	no
F014-H	3	-2481.731	60.000	-616.029	0.0	54.3	no
F014-S	3	-2481.596	60.000	-627.741	0.0	39.3	no
F015-H	3	-2482.016	60.000	-620.988	0.0	51.6	no
F015-S	3	-2481.920	60.000	-620.364	0.0	59.4	no
F016-H	3	-2481.501	60.000	-621.028	90.0	23.4	m/b
F016-S	3	-2481.522	125.000	-710.850	0.0	18.9	FLY
F017-H	3	-2481.614	125.000	-733.301	0.0	69.0	FLY
F017-S	3	-2481.438	60.000	-622.307	0.0	39.6	no
F018-H	3	-2481.307	125.000	-708.485	0.0	41.4	FLY
F018-S	3	-2481.430	60.000	-625.628	0.0	14.4	no
F019-H	3	-2482.561	125.000	-712.932	0.0	82.5	FLY

F019-S	3	-2481.310	119.000	-713.758	0.0	72.0	FLY
F020-H	3	-2481.411	60.000	-619.783	0.0	43.5	no
F020-S	3	-2481.511	60.000	-620.231	0.0	31.2	no
F021-H	3	-2481.687	125.000	-715.381	0.0	40.2	FLY
F021-S	3	-2482.106	60.000	-618.853	0.0	76.2	no
F022-H	3	-2482.039	60.000	-637.108	0.0	64.2	no
F022-S	3	-2481.471	60.000	-626.989	0.0	43.5	no
F023-H	3	-2481.529	125.000	-728.215	0.0	27.0	FLY
F023-S	3	-2482.171	60.000	-621.315	0.0	71.7	no
F024-H	3	-2481.567	125.000	-727.448	0.0	46.5	FLY
F024-S	3	-2481.424	60.000	-634.669	90.0	26.4	m/b
F025-H	3	-2481.484	60.000	-615.807	0.0	34.5	no
F025-S	3	-2481.337	60.000	-622.217	0.0	41.1	no
F026-H	3	-2481.402	60.000	-618.418	0.0	37.5	no
F026-S	3	-2481.368	60.000	-620.673	0.0	39.0	no
F027-H	3	-2481.629	125.000	-705.402	0.0	34.2	FLY
F027-S	3	-2481.565	60.000	-623.117	0.0	87.3	no
F028-H	3	-2481.749	60.000	-627.018	0.0	51.6	no
F028-S	3	-2481.720	60.000	-636.032	0.0	42.9	no
F029-H	3	-2481.527	125.000	-711.373	0.0	23.7	FLY
F029-S	3	-2481.499	60.000	-616.056	0.0	32.1	no
F030-H	3	-2481.899	60.000	-615.400	0.0	43.5	no
F030-S	3	-2481.271	60.000	-624.677	0.0	38.4	no
F031-H	3	-2481.443	60.000	-622.024	0.0	24.9	no
F031-S	3	-2481.518	60.000	-620.755	0.0	65.7	no
F032-H	3	-2481.713	60.000	-624.150	0.0	87.0	no
F032-S	3	-2481.897	60.000	-623.568	0.0	51.9	no
F033-H	3	-2482.326	125.000	-715.375	0.0	74.4	FLY
F033-S	3	-2481.804	98.000	-721.115	0.0	114.0	FLY
F034-H	3	-2482.567	121.000	-722.362	0.0	87.3	FLY
F034-S	3	-2481.426	60.000	-627.220	90.0	45.3	m/b
F035-H	3	-2481.680	63.000	-714.184	0.0	28.8	FLY
F035-S	3	-2481.345	60.000	-615.889	90.0	27.9	m/b
F036-H	3	-2481.601	125.000	-714.033	0.0	24.3	FLY
F036-S	3	-2481.572	125.000	-709.355	0.0	20.4	FLY
F037-H	3	-2481.678	60.000	-635.245	0.0	45.0	no
F037-S	3	-2481.303	60.000	-622.205	0.0	54.3	no
F038-H	3	-2481.519	68.000	-710.922	0.0	67.8	FLY
F038-S	3	-2482.386	76.000	-713.833	0.0	72.9	FLY
F040-H	3	-2481.628	60.000	-625.014	0.0	35.1	no
F040-S	3	-2481.557	60.000	-614.106	0.0	25.8	no
F041-H	3	-2481.613	60.000	-634.319	0.0	29.4	no
F041-S	3	-2481.638	60.000	-632.947	0.0	31.2	no
F042-H	3	-2481.484	60.000	-626.642	0.0	38.7	no
F042-S	3	-2481.546	60.000	-629.784	0.0	21.9	no
F043-H	3	-2481.591	60.000	-620.237	0.0	23.1	no
F043-S	3	-2481.745	60.000	-622.046	0.0	34.5	no
H001-H	3	-2481.422	60.000	-612.151	0.0	39.0	no
H002-H	3	-2481.371	60.000	-624.325	0.0	17.1	no
H003-H	3	-2481.369	125.000	-731.211	0.0	31.5	FLY
I001-H	3	-2481.383	117.000	-718.549	0.0	39.0	FLY
I001-S	3	-2481.553	60.000	-618.970	0.0	24.6	no
P001-H	3	-2481.873	154.000	-708.284	0.0	48.3	FLY
P001-S	3	-2481.793	248.000	-701.468	0.0	57.6	FLY
P002-H	3	-2481.802	60.000	-633.407	0.0	78.6	no
P002-S	3	-2481.777	120.000	-711.087	0.0	44.4	FLY
P003-H	3	-2481.300	60.000	-633.214	0.0	12.9	no
P003-S	3	-2481.485	60.000	-622.239	0.0	24.0	no
P004-H	3	-2481.361	60.000	-634.101	90.0	50.4	m/b
P004-S	3	-2481.648	60.000	-620.843	0.0	29.4	no

File	Room	X	Y	Z	Rotate	Speed	RESULT
P005-H	3	-2481.381	152.000	-702.515	0.0	18.3	FLY
P005-S	3	-2481.312	158.000	-711.241	0.0	45.3	FLY
P006-H	3	-2481.752	60.000	-625.742	0.0	54.3	no
P006-S	3	-2481.466	60.000	-623.996	0.0	21.0	no
P007-H	3	-2481.424	250.000	-663.581	0.0	46.2	FLY
P007-S	3	-2481.547	250.000	-671.354	0.0	28.5	FLY
P008-H	3	-2482.333	60.000	-721.223	0.0	67.8	no
P008-S	3	-2481.349	196.000	-717.523	0.0	40.2	FLY
P009-H	3	-2481.606	156.000	-706.062	0.0	34.2	FLY
P009-S	3	-2482.093	140.000	-704.627	0.0	96.6	FLY
P010-H	3	-2481.935	60.000	-631.309	0.0	47.1	no
P010-S	3	-2481.728	60.000	-645.090	0.0	43.8	no

Task Room 4 Reduced Data

File	Room	X	Y	Z	Rotate	Speed	RESULT
A001-H	4	-2344.832	60.000	-221.714	90.0	49.5	ROTATE
A002-H	4	-2346.762	60.000	-221.742	90.0	35.1	ROTATE
A003-H	4	-2343.354	60.000	-221.774	90.0	30.9	ROTATE
A004-H	4	-2343.870	60.000	-222.091	0.0	69.6	no
A005-H	4	-2341.650	60.000	-222.530	90.0	85.8	ROTATE
B001-H	4	-2334.710	60.000	-221.507	0.0	13.5	no
B001-S	4	-2359.634	60.000	-221.805	0.0	22.2	no
B002-H	4	-2335.057	60.000	-221.593	90.0	37.2	ROTATE
B002-S	4	-2358.431	60.000	-222.569	0.0	69.9	no
B003-H	4	-2332.665	60.000	-221.570	0.0	38.1	no
B003-S	4	-2360.673	60.000	-222.209	0.0	58.2	no
B004-H	4	-2334.902	60.000	-222.269	69.0	55.2	ROTATE
B004-S	4	-2358.103	60.000	-222.284	0.0	74.4	no
B005-H	4	-2336.080	60.000	-221.826	90.0	21.3	ROTATE
B005-S	4	-2354.984	60.000	-221.824	0.0	41.1	no
F001-H	4	-2358.067	60.000	-221.696	0.0	22.5	no
F001-S	4	-2359.879	60.000	-221.540	90.0	66.0	ROTATE
F002-H	4	-2356.503	60.000	-222.872	90.0	98.1	ROTATE
F002-S	4	-2358.592	60.000	-222.328	90.0	77.7	ROTATE
F003-H	4	-2349.964	60.000	-222.050	90.0	90.9	ROTATE
F003-S	4	-2359.009	60.000	-222.300	66.0	127.8	ROTATE
F004-H	4	-2360.862	60.000	-222.955	0.0	94.8	no
F004-S	4	-2352.895	60.000	-222.198	0.0	66.9	no
F005-H	4	-2356.644	60.000	-221.956	90.0	47.1	ROTATE
F005-S	4	-2357.422	60.000	-221.737	0.0	95.7	no
F006-H	4	-2358.169	60.000	-222.535	0.0	88.8	no
F006-S	4	-2356.614	60.000	-221.946	0.0	63.3	no
F007-H	4	-2358.475	60.000	-221.526	0.0	65.1	no
F007-S	4	-2358.507	60.000	-221.614	0.0	54.6	no
F008-H	4	-2358.201	60.000	-221.602	69.0	37.5	ROTATE
F008-S	4	-2357.485	60.000	-221.667	0.0	25.8	no
F009-H	4	-2353.980	60.000	-222.582	90.0	85.5	ROTATE
F009-S	4	-2358.360	60.000	-222.499	0.0	147.6	no
F010-H	4	-2354.355	60.000	-222.297	90.0	63.6	ROTATE
F010-S	4	-2358.484	60.000	-221.536	0.0	12.6	no
F011-H	4	-2361.468	60.000	-221.667	0.0	27.3	no
F011-S	4	-2358.713	60.000	-221.760	0.0	25.5	no
F012-H	4	-2363.801	60.000	-221.738	0.0	50.7	no
F012-S	4	-2364.439	60.000	-221.855	0.0	28.8	no
F013-H	4	-2357.674	60.000	-222.253	0.0	48.6	no
F013-S	4	-2355.001	60.000	-221.564	0.0	112.8	no
F014-H	4	-2360.108	60.000	-222.149	0.0	49.8	no
F014-S	4	-2354.160	60.000	-221.675	0.0	47.4	no
F015-H	4	-2360.857	60.000	-221.962	0.0	78.0	no

F015-S	4	-2359.743	60.000	-222.099	0.0	50.1	no
F016-H	4	-2358.495	60.000	-221.726	90.0	18.0	ROTATE
F016-S	4	-2359.820	60.000	-221.949	90.0	57.9	ROTATE
F017-H	4	-2357.738	60.000	-221.545	0.0	33.6	no
F017-S	4	-2356.956	60.000	-221.685	0.0	48.0	no
F018-H	4	-2358.556	60.000	-222.227	0.0	53.4	no
F018-S	4	-2360.597	60.000	-221.506	0.0	26.7	no
F019-H	4	-2362.172	60.000	-222.403	90.0	62.7	ROTATE
F019-S	4	-2357.720	60.000	-222.540	72.0	99.9	ROTATE
F020-H	4	-2357.337	60.000	-221.759	0.0	46.8	no
F020-S	4	-2358.426	60.000	-221.975	0.0	30.9	no
F021-H	4	-2361.115	60.000	-222.015	0.0	65.4	no
F021-S	4	-2359.496	60.000	-222.368	0.0	94.5	no
F022-H	4	-2342.152	60.000	-222.788	0.0	99.0	no
F022-S	4	-2354.867	60.000	-222.211	0.0	46.8	no
F023-H	4	-2358.163	60.000	-221.969	0.0	40.5	no
F023-S	4	-2362.347	60.000	-222.270	0.0	72.9	no
F024-H	4	-2355.128	60.000	-222.019	90.0	47.4	ROTATE
F024-S	4	-2357.394	60.000	-221.608	0.0	24.3	no
F025-H	4	-2361.234	60.000	-221.765	0.0	27.6	no
F025-S	4	-2358.761	60.000	-222.056	0.0	47.4	no
F026-H	4	-2355.074	60.000	-222.585	0.0	85.2	no
F026-S	4	-2357.184	60.000	-221.655	0.0	54.6	no
F027-H	4	-2357.118	60.000	-221.850	0.0	46.8	no
F027-S	4	-2356.123	60.000	-222.986	0.0	103.2	no
F028-H	4	-2356.532	60.000	-222.721	0.0	90.0	no
F028-S	4	-2361.020	60.000	-221.571	0.0	150.0	no
F029-H	4	-2357.980	60.000	-221.503	90.0	45.3	ROTATE
F029-S	4	-2357.523	60.000	-221.777	90.0	47.1	ROTATE
F030-H	4	-2359.433	60.000	-222.040	0.0	43.2	no
F030-S	4	-2360.308	60.000	-221.945	0.0	53.1	no
F031-H	4	-2360.347	60.000	-221.845	0.0	35.7	no
F031-S	4	-2361.634	60.000	-221.582	0.0	62.4	no
F032-H	4	-2363.446	60.000	-221.668	0.0	103.5	no
F032-S	4	-2354.766	60.000	-222.020	0.0	45.3	no
F033-H	4	-2355.875	60.000	-222.090	0.0	75.9	no
F033-S	4	-2359.464	60.000	-222.352	0.0	139.5	no
F034-H	4	-2358.201	60.000	-222.094	0.0	71.1	no
F034-S	4	-2358.733	60.000	-221.911	0.0	54.6	no
F035-H	4	-2358.368	60.000	-221.876	90.0	35.7	ROTATE
F035-S	4	-2360.066	60.000	-221.635	90.0	42.3	ROTATE
F036-H	4	-2360.279	60.000	-222.060	0.0	46.5	no
F036-S	4	-2356.090	60.000	-221.704	90.0	32.1	ROTATE
F037-H	4	-2357.879	60.000	-221.546	0.0	39.9	no
F037-S	4	-2359.775	60.000	-221.898	0.0	69.3	no
F038-H	4	-2348.386	60.000	-221.519	0.0	70.2	no
F038-S	4	-2356.900	60.000	-222.348	0.0	69.0	no
F040-H	4	-2360.638	60.000	-221.502	0.0	41.4	no
F040-S	4	-2358.966	60.000	-222.111	0.0	42.0	no
F041-H	4	-2356.357	60.000	-221.758	0.0	20.4	no
F041-S	4	-2358.274	60.000	-221.982	18.0	34.2	ROTATE
F042-H	4	-2358.652	60.000	-221.598	0.0	40.8	no
F042-S	4	-2359.727	60.000	-221.850	0.0	23.1	no
F043-H	4	-2362.227	60.000	-221.501	0.0	18.6	no
F043-S	4	-2356.812	60.000	-221.644	0.0	30.9	no
H001-H	4	-2359.275	60.000	-221.964	0.0	45.6	no
H002-H	4	-2357.697	60.000	-221.848	0.0	26.4	no
H003-H	4	-2358.149	60.000	-221.634	0.0	39.9	no
I001-H	4	-2362.430	60.000	-221.508	0.0	81.6	no
I001-S	4	-2361.924	60.000	-221.940	0.0	33.9	no

File	Room	X	Y	Z	Rotate	Speed	RESULT
P001-H	4	-2355.639	60.000	-222.222	63.0	78.9	ROTATE
P001-S	4	-2358.224	60.000	-222.454	0.0	71.7	no
P002-H	4	-2355.066	60.000	-222.013	90.0	79.5	ROTATE
P002-S	4	-2359.857	60.000	-221.870	0.0	54.6	no
P003-H	4	-2359.249	60.000	-221.586	90.0	10.8	ROTATE
P003-S	4	-2357.335	60.000	-221.536	0.0	24.9	no
P004-H	4	-2353.687	60.000	-221.573	90.0	42.0	ROTATE
P004-S	4	-2357.402	60.000	-221.714	0.0	36.6	no
P005-H	4	-2357.466	60.000	-221.661	0.0	38.7	no
P005-S	4	-2357.102	60.000	-221.947	90.0	81.6	ROTATE
P006-H	4	-2355.223	60.000	-221.758	0.0	27.0	no
P006-S	4	-2358.195	60.000	-221.958	0.0	45.9	no
P007-H	4	-2360.704	60.000	-221.914	0.0	49.8	no
P007-S	4	-2358.149	60.000	-221.789	0.0	20.7	no
P008-H	4	-2347.134	60.000	-221.830	0.0	53.1	no
P008-S	4	-2355.877	60.000	-222.006	0.0	52.2	no
P009-H	4	-2361.513	60.000	-222.553	0.0	69.6	no
P009-S	4	-2359.495	60.000	-222.940	0.0	143.4	no
P010-H	4	-2350.182	60.000	-222.385	0.0	65.4	no
P010-S	4	-2356.389	60.000	-222.066	0.0	36.3	no

Task Room 5 Reduced Data

File	Room	X	Y	Z	Rotate	Speed	RESULT
A001-H	5	-1892.275	60.000	-153.655	0.0	56.4	CATCH
A002-H	5	-1892.052	60.000	-30.141	0.0	48.0	not
A003-H	5	-1892.447	60.000	-142.843	0.0	43.8	CATCH
A004-H	5	-1891.944	60.000	-149.713	0.0	76.5	CATCH
A005-H	5	-1891.789	60.000	-139.851	0.0	45.9	CATCH
B001-H	5	-1891.907	60.000	-150.231	0.0	15.9	CATCH
B001-S	5	-1891.761	60.000	-143.561	0.0	22.2	CATCH
B002-H	5	-1892.477	60.000	-147.343	0.0	45.3	CATCH
B002-S	5	-1892.166	60.000	-148.458	0.0	59.1	CATCH
B003-H	5	-1891.857	60.000	-151.756	0.0	41.7	CATCH
B003-S	5	-1892.417	60.000	-146.790	0.0	64.5	CATCH
B004-H	5	-1892.323	60.000	-149.031	0.0	63.6	CATCH
B004-S	5	-1892.969	60.000	-148.331	0.0	87.9	CATCH
B005-H	5	-1891.838	60.000	-52.291	0.0	54.3	not
B005-S	5	-1891.914	60.000	-140.863	0.0	20.7	CATCH
F001-H	5	-1891.850	60.000	-153.151	0.0	30.9	CATCH
F001-S	5	-1891.964	60.000	-152.276	0.0	37.2	CATCH
F002-H	5	-1892.219	60.000	-48.053	0.0	78.6	not
F002-S	5	-1892.475	60.000	-55.443	0.0	63.3	not
F003-H	5	-1891.825	60.000	-148.040	0.0	37.2	CATCH
F003-S	5	-1891.779	60.000	-131.844	0.0	145.8	CATCH
F004-H	5	-1892.751	60.000	-125.678	0.0	109.8	CATCH
F004-S	5	-1892.410	60.000	-141.256	0.0	45.3	CATCH
F005-H	5	-1892.376	60.000	-96.059	0.0	150.0	not
F005-S	5	-1892.875	60.000	-143.228	0.0	93.9	CATCH
F006-H	5	-1893.196	60.000	-153.472	0.0	88.8	CATCH
F006-S	5	-1892.504	60.000	-151.210	0.0	61.2	CATCH
F007-H	5	-1892.537	60.000	-143.710	0.0	52.2	CATCH
F007-S	5	-1891.896	60.000	-138.623	0.0	57.9	CATCH
F008-H	5	-1892.221	60.000	-145.087	0.0	38.7	CATCH
F008-S	5	-1892.437	60.000	-142.533	0.0	41.1	CATCH
F009-H	5	-1892.179	60.000	-150.071	90.0	63.9	CATCH
F009-S	5	-1892.814	98.000	-138.825	0.0	147.3	CATCH
F010-H	5	-1892.296	60.000	-148.023	0.0	83.7	CATCH
F010-S	5	-1892.031	60.000	-147.923	0.0	39.9	CATCH
F011-H	5	-1891.804	60.000	-152.526	0.0	24.6	CATCH

F011-S	5	-1892.442	60.000	-29.383	0.0	48.6	not
F012-H	5	-1892.321	60.000	-142.578	0.0	44.4	CATCH
F012-S	5	-1892.270	60.000	-142.221	0.0	42.6	CATCH
F013-H	5	-1892.747	60.000	-148.755	0.0	67.8	CATCH
F013-S	5	-1892.067	60.000	-133.125	0.0	121.5	CATCH
F014-H	5	-1892.567	60.000	-146.829	0.0	55.2	CATCH
F014-S	5	-1892.394	60.000	-152.298	0.0	58.8	CATCH
F015-H	5	-1892.823	60.000	-144.968	0.0	73.8	CATCH
F015-S	5	-1892.340	60.000	-142.005	0.0	74.4	CATCH
F016-H	5	-1891.890	60.000	-145.204	90.0	15.3	CATCH
F016-S	5	-1892.019	66.000	-42.464	18.0	54.3	not
F017-H	5	-1892.428	60.000	-151.684	0.0	41.4	CATCH
F017-S	5	-1891.815	60.000	-140.163	0.0	45.6	CATCH
F018-H	5	-1892.197	60.000	-151.687	0.0	46.2	CATCH
F018-S	5	-1891.907	60.000	-146.580	0.0	31.5	CATCH
F019-H	5	-1892.406	60.000	-141.110	0.0	49.5	CATCH
F019-S	5	-1891.866	60.000	-143.040	0.0	56.7	CATCH
F020-H	5	-1892.561	60.000	-148.327	0.0	50.1	CATCH
F020-S	5	-1892.265	60.000	-145.001	0.0	41.4	CATCH
F021-H	5	-1892.146	60.000	-144.883	0.0	72.3	CATCH
F021-S	5	-1892.063	60.000	-140.792	0.0	91.5	CATCH
F022-H	5	-1892.073	60.000	-149.503	0.0	71.1	CATCH
F022-S	5	-1892.331	60.000	-143.273	0.0	50.7	CATCH
F023-H	5	-1892.166	60.000	-148.825	0.0	50.4	CATCH
F023-S	5	-1891.938	60.000	-149.367	0.0	80.7	CATCH
F024-H	5	-1891.832	60.000	-148.592	90.0	34.5	CATCH
F024-S	5	-1892.046	60.000	-151.478	0.0	26.7	CATCH
F025-H	5	-1892.233	60.000	-148.553	0.0	49.5	CATCH
F025-S	5	-1892.334	60.000	-146.512	0.0	67.5	CATCH
F026-H	5	-1892.287	60.000	-143.756	0.0	67.5	CATCH
F026-S	5	-1891.776	60.000	-147.045	0.0	36.6	CATCH
F027-H	5	-1892.476	60.000	-147.438	0.0	52.5	CATCH
F027-S	5	-1891.989	60.000	-148.668	0.0	78.3	CATCH
F028-H	5	-1892.404	60.000	-148.308	0.0	99.9	CATCH
F028-S	5	-1891.815	60.000	-142.126	0.0	21.6	CATCH
F029-H	5	-1892.121	60.000	-146.563	90.0	43.8	CATCH
F029-S	5	-1891.878	60.000	-25.022	0.0	25.8	not
F030-H	5	-1891.758	60.000	-35.841	0.0	51.0	not
F030-S	5	-1891.912	60.000	-145.185	0.0	56.7	CATCH
F031-H	5	-1892.185	60.000	-146.999	0.0	38.7	CATCH
F031-S	5	-1892.232	60.000	-142.096	0.0	69.3	CATCH
F032-H	5	-1892.698	60.000	-148.045	0.0	66.3	CATCH
F032-S	5	-1892.001	60.000	-147.554	0.0	65.4	CATCH
F033-H	5	-1891.993	60.000	-34.237	0.0	48.9	not
F033-S	5	-1893.881	60.000	-144.915	0.0	132.3	CATCH
F034-H	5	-1892.780	60.000	-154.598	0.0	69.3	CATCH
F034-S	5	-1891.907	60.000	-151.472	0.0	64.8	CATCH
F035-H	5	-1892.192	60.000	-143.107	90.0	33.0	CATCH
F035-S	5	-1891.860	60.000	-143.963	90.0	34.2	CATCH
F036-H	5	-1891.993	60.000	-145.599	0.0	43.8	CATCH
F036-S	5	-1891.874	60.000	-33.384	0.0	20.7	not
F037-H	5	-1892.335	60.000	-146.273	0.0	43.8	CATCH
F037-S	5	-1892.302	60.000	-145.809	0.0	79.5	CATCH
F038-H	5	-1892.000	60.000	-155.716	0.0	48.6	CATCH
F038-S	5	-1892.361	60.000	-154.952	0.0	48.3	CATCH
F040-H	5	-1891.875	60.000	-148.215	0.0	36.3	CATCH
F040-S	5	-1892.125	60.000	-144.605	0.0	31.8	CATCH
F041-H	5	-1891.782	60.000	-151.350	0.0	12.6	CATCH
F041-S	5	-1891.751	60.000	-152.126	0.0	37.5	CATCH
F042-H	5	-1892.140	60.000	-152.471	0.0	46.5	CATCH

File	Room	X	Y	Z	Rotate	Speed	RESULT
F042-S	5	-1892.314	60.000	-149.739	0.0	45.6	CATCH
F043-H	5	-1892.046	60.000	-146.035	0.0	27.3	CATCH
F043-S	5	-1891.999	60.000	-37.579	0.0	26.4	not
H001-H	5	-1892.111	60.000	-149.560	0.0	37.5	CATCH
H002-H	5	-1892.086	60.000	-150.133	0.0	40.2	CATCH
H003-H	5	-1891.879	60.000	-149.726	0.0	48.9	CATCH
I001-H	5	-1892.702	60.000	-151.004	0.0	59.4	CATCH
I001-S	5	-1892.345	60.000	-41.255	0.0	45.6	not
P001-H	5	-1892.375	60.000	-33.208	81.0	65.1	not
P001-S	5	-1892.181	60.000	-137.093	0.0	63.6	CATCH
P002-H	5	-1892.606	60.000	-51.416	0.0	58.5	not
P002-S	5	-1892.058	60.000	-43.072	0.0	51.9	not
P003-H	5	-1891.950	60.000	-153.933	0.0	13.8	CATCH
P003-S	5	-1892.006	60.000	-145.916	0.0	38.4	CATCH
P004-H	5	-1891.837	60.000	-148.834	0.0	56.1	CATCH
P004-S	5	-1892.089	60.000	-151.695	0.0	42.3	CATCH
P005-H	5	-1892.214	60.000	-144.263	0.0	30.0	CATCH
P005-S	5	-1891.996	60.000	-147.352	90.0	41.4	CATCH
P006-H	5	-1892.544	60.000	-153.013	0.0	58.5	CATCH
P006-S	5	-1892.137	60.000	-146.953	0.0	41.7	CATCH
P007-H	5	-1891.849	60.000	-154.641	0.0	11.7	CATCH
P007-S	5	-1891.824	60.000	-150.178	0.0	37.5	CATCH
P008-H	5	-1892.171	60.000	-147.812	0.0	69.0	CATCH
P008-S	5	-1892.252	60.000	-145.525	0.0	122.4	CATCH
P009-H	5	-1892.456	60.000	-143.397	0.0	57.0	CATCH
P009-S	5	-1892.932	60.000	-146.711	0.0	121.8	CATCH
P010-H	5	-1892.343	60.000	-137.826	0.0	59.1	CATCH
P010-S	5	-1891.795	60.000	-155.469	0.0	19.8	CATCH

Task Room 6 Reduced Data

File	Room	X	Y	Z	Rotate	Speed	RESULT
A001-H	6	-1825.640	60.000	-564.137	63.0	38.4	m/b
A002-H	6	-1818.802	60.000	-563.887	0.0	61.2	no
A003-H	6	-1824.991	60.000	-563.901	90.0	42.6	m/b
A004-H	6	-1814.629	60.000	-563.546	0.0	84.3	no
A005-H	6	-1816.422	60.000	-564.358	0.0	62.7	no
B001-H	6	-1816.432	60.000	-564.473	0.0	15.0	no
B001-S	6	-1726.895	95.000	-564.321	0.0	16.5	FLY
B002-H	6	-1717.786	125.000	-564.424	0.0	47.1	FLY
B002-S	6	-1705.721	125.000	-563.966	0.0	57.0	FLY
B003-H	6	-1821.533	60.000	-564.246	0.0	50.7	no
B003-S	6	-1726.027	71.000	-563.636	0.0	67.8	FLY
B004-H	6	-1722.231	125.000	-563.812	0.0	72.9	FLY
B004-S	6	-1713.977	125.000	-563.264	0.0	84.9	FLY
B005-H	6	-1726.054	60.000	-564.328	0.0	21.9	no
B005-S	6	-1809.324	60.000	-564.357	0.0	32.1	no
F001-H	6	-1709.612	60.000	-564.235	0.0	16.8	no
F001-S	6	-1693.123	125.000	-564.384	0.0	31.2	FLY
F002-H	6	-1730.390	109.000	-563.086	0.0	99.0	FLY
F002-S	6	-1731.249	107.000	-563.999	0.0	65.1	FLY
F003-H	6	-1733.375	125.000	-564.384	0.0	63.9	FLY
F003-S	6	-1727.452	125.000	-564.263	0.0	150.0	FLY
F004-H	6	-1816.752	60.000	-563.334	0.0	109.8	no
F004-S	6	-1707.060	121.000	-563.991	0.0	65.7	FLY
F005-H	6	-1722.442	125.000	-562.227	0.0	136.2	FLY
F005-S	6	-1717.314	123.000	-562.685	0.0	150.0	FLY
F006-H	6	-1717.447	115.000	-563.760	0.0	89.4	FLY
F006-S	6	-1716.806	107.000	-563.978	0.0	72.3	FLY
F007-H	6	-1720.936	125.000	-564.205	0.0	53.7	FLY

F007-S	6	-1718.954	125.000	-564.195	0.0	40.2	FLY
F008-H	6	-1731.036	125.000	-564.078	0.0	41.7	FLY
F008-S	6	-1732.179	125.000	-563.999	0.0	57.9	FLY
F009-H	6	-1724.661	125.000	-563.585	0.0	61.5	FLY
F009-S	6	-1715.659	125.000	-563.346	0.0	129.0	FLY
F010-H	6	-1731.313	125.000	-563.927	0.0	87.3	FLY
F010-S	6	-1713.143	125.000	-564.243	0.0	29.1	FLY
F011-H	6	-1815.555	60.000	-564.213	0.0	37.2	no
F011-S	6	-1729.834	121.000	-564.317	0.0	26.7	FLY
F012-H	6	-1735.536	65.000	-564.236	0.0	74.7	FLY
F012-S	6	-1723.995	81.000	-564.355	0.0	67.2	FLY
F013-H	6	-1711.106	69.000	-564.175	0.0	65.4	FLY
F013-S	6	-1806.203	60.000	-563.574	0.0	119.4	no
F014-H	6	-1735.051	87.000	-564.213	0.0	47.4	FLY
F014-S	6	-1722.778	125.000	-564.464	0.0	51.9	FLY
F015-H	6	-1715.588	125.000	-563.636	0.0	71.1	FLY
F015-S	6	-1724.353	125.000	-563.746	0.0	86.1	FLY
F016-H	6	-1723.323	60.000	-564.442	0.0	22.8	no
F016-S	6	-1816.336	60.000	-564.415	90.0	31.2	m/b
F017-H	6	-1718.772	60.000	-564.155	0.0	47.7	no
F017-S	6	-1709.330	123.000	-563.812	0.0	63.6	FLY
F018-H	6	-1726.355	69.000	-564.440	0.0	48.0	FLY
F018-S	6	-1718.929	125.000	-564.159	0.0	24.6	FLY
F019-H	6	-1715.615	95.000	-563.485	0.0	71.7	FLY
F019-S	6	-1705.242	80.000	-563.984	0.0	94.5	FLY
F020-H	6	-1734.481	125.000	-564.333	0.0	49.8	FLY
F020-S	6	-1727.742	125.000	-564.412	0.0	36.3	FLY
F021-H	6	-1722.296	125.000	-564.168	0.0	82.8	FLY
F021-S	6	-1713.607	125.000	-563.149	0.0	86.4	FLY
F022-H	6	-1820.705	60.000	-563.313	0.0	80.4	no
F022-S	6	-1816.345	60.000	-563.491	0.0	62.4	no
F023-H	6	-1717.944	125.000	-564.067	0.0	54.3	FLY
F023-S	6	-1702.224	125.000	-563.226	0.0	91.2	FLY
F024-H	6	-1715.125	75.000	-564.400	0.0	46.5	FLY
F024-S	6	-1725.472	119.000	-564.189	0.0	19.8	FLY
F025-H	6	-1712.891	99.000	-563.741	0.0	53.1	FLY
F025-S	6	-1710.020	125.000	-563.794	0.0	72.0	FLY
F026-H	6	-1721.010	125.000	-564.459	0.0	76.2	FLY
F026-S	6	-1724.898	125.000	-564.321	0.0	58.5	FLY
F027-H	6	-1721.536	93.000	-564.402	0.0	40.2	FLY
F027-S	6	-1718.829	125.000	-564.175	0.0	90.3	FLY
F028-H	6	-1822.790	60.000	-564.277	90.0	45.0	m/b
F028-S	6	-1721.798	125.000	-563.750	0.0	64.2	FLY
F029-H	6	-1733.686	85.000	-564.115	0.0	46.5	FLY
F029-S	6	-1721.526	125.000	-564.072	0.0	57.6	FLY
F030-H	6	-1715.168	125.000	-564.192	0.0	68.7	FLY
F030-S	6	-1702.828	121.000	-564.042	0.0	51.0	FLY
F031-H	6	-1733.853	75.000	-564.005	0.0	43.2	FLY
F031-S	6	-1726.303	126.000	-563.635	0.0	70.5	FLY
F032-H	6	-1731.491	69.000	-563.796	0.0	76.2	FLY
F032-S	6	-1732.960	125.000	-563.958	0.0	54.0	FLY
F033-H	6	-1722.097	108.000	-564.402	0.0	110.1	FLY
F033-S	6	-1824.168	60.000	-563.350	0.0	112.2	no
F034-H	6	-1713.156	67.000	-563.846	0.0	67.8	FLY
F034-S	6	-1825.294	60.000	-564.137	72.0	62.1	m/b
F035-H	6	-1815.669	60.000	-564.486	90.0	36.0	m/b
F035-S	6	-1714.367	121.000	-564.262	0.0	44.4	FLY
F036-H	6	-1728.362	125.000	-564.399	0.0	38.1	FLY
F036-S	6	-1823.045	60.000	-564.301	0.0	29.1	no
F037-H	6	-1726.049	125.000	-564.217	0.0	61.5	FLY

File	Room	X	Y	Z	Rotate	Speed	RESULT
F037-S	6	-1711.864	115.000	-563.791	0.0	82.2	FLY
F038-H	6	-1814.426	60.000	-564.432	90.0	56.7	m/b
F038-S	6	-1718.779	60.000	-563.996	0.0	42.3	no
F040-H	6	-1741.465	97.000	-564.128	0.0	49.8	FLY
F040-S	6	-1821.642	60.000	-564.373	0.0	32.1	no
F041-H	6	-1813.961	60.000	-564.307	0.0	41.1	no
F041-S	6	-1710.037	60.000	-564.326	0.0	56.7	no
F042-H	6	-1726.825	60.000	-564.380	0.0	57.3	no
F042-S	6	-1815.737	60.000	-564.259	0.0	47.1	no
F043-H	6	-1819.728	60.000	-564.443	0.0	14.1	no
F043-S	6	-1823.886	60.000	-564.241	0.0	50.4	no
H001-H	6	-1715.716	65.000	-563.886	0.0	63.3	FLY
H002-H	6	-1704.758	60.000	-563.924	0.0	44.7	no
H003-H	6	-1695.686	125.000	-563.784	0.0	55.8	FLY
I001-H	6	-1721.600	73.000	-563.921	0.0	63.0	FLY
I001-S	6	-1820.139	60.000	-563.871	0.0	62.4	no
P001-H	6	-1825.357	60.000	-563.981	90.0	57.0	m/b
P001-S	6	-1727.622	80.000	-563.392	0.0	75.0	FLY
P002-H	6	-1713.279	60.000	-564.475	0.0	48.9	no
P002-S	6	-1712.685	250.000	-564.428	0.0	44.4	FLY
P003-H	6	-1709.365	250.000	-564.027	0.0	33.0	FLY
P003-S	6	-1802.155	60.000	-564.284	90.0	36.0	m/b
P004-H	6	-1726.375	200.000	-563.773	0.0	56.1	FLY
P004-S	6	-1807.776	60.000	-563.815	0.0	48.9	no
P005-H	6	-1719.557	244.000	-564.158	0.0	32.7	FLY
P005-S	6	-1727.854	184.000	-564.022	0.0	59.4	FLY
P006-H	6	-1720.340	58.000	-563.579	0.0	59.1	no
P006-S	6	-1710.604	168.000	-564.049	0.0	28.5	FLY
P007-H	6	-1814.434	60.000	-564.307	90.0	22.2	m/b
P007-S	6	-1715.525	234.000	-563.985	0.0	44.1	FLY
P008-H	6	-1817.505	60.000	-563.843	0.0	54.6	no
P008-S	6	-1804.104	60.000	-564.084	0.0	83.4	no
P009-H	6	-1820.731	60.000	-563.991	0.0	61.5	no
P009-S	6	-1728.856	124.000	-563.630	0.0	147.9	FLY
P010-H	6	-1805.235	60.000	-563.799	0.0	68.4	no
P010-S	6	-1796.315	60.000	-564.456	0.0	39.9	no

Task Room 7 Reduced Data

File	Room	X	Y	Z	Rotate	Speed	RESULT
A001-H	7	-1302.256	60.000	-690.515	90.0	48.0	ROTATE
A002-H	7	-1302.519	60.000	-686.951	90.0	63.0	ROTATE
A003-H	7	-1302.438	60.000	-686.521	90.0	64.8	ROTATE
A004-H	7	-1303.364	60.000	-699.370	0.0	72.6	no
A005-H	7	-1303.136	60.000	-693.451	90.0	66.3	ROTATE
B001-H	7	-1302.294	60.000	-698.826	0.0	13.8	no
B001-S	7	-1302.485	60.000	-684.405	0.0	23.7	no
B002-H	7	-1302.978	60.000	-699.535	90.0	54.9	ROTATE
B002-S	7	-1302.361	60.000	-696.355	84.0	51.6	ROTATE
B003-H	7	-1302.917	60.000	-693.633	0.0	45.3	no
B003-S	7	-1302.478	60.000	-690.380	0.0	54.3	no
B004-H	7	-1302.324	60.000	-688.247	72.0	44.4	ROTATE
B004-S	7	-1302.485	60.000	-695.685	90.0	74.4	ROTATE
B005-H	7	-1302.338	60.000	-700.765	90.0	18.0	ROTATE
B005-S	7	-1302.307	60.000	-691.169	0.0	36.9	no
F001-H	7	-1302.678	60.000	-701.028	90.0	29.4	ROTATE
F001-S	7	-1302.647	60.000	-693.209	90.0	27.3	ROTATE
F002-H	7	-1303.239	60.000	-693.176	90.0	72.9	ROTATE
F002-S	7	-1302.320	60.000	-698.457	90.0	65.7	ROTATE
F003-H	7	-1302.457	60.000	-697.123	90.0	66.9	ROTATE

161

F003-S	7	-1304.140	60.000	-691.160	90.0	133.2	ROTATE
F004-H	7	-1303.006	60.000	-692.052	0.0	67.5	no
F004-S	7	-1302.927	60.000	-702.097	0.0	51.0	no
F005-H	7	-1302.342	60.000	-689.084	90.0	81.9	ROTATE
F005-S	7	-1304.133	60.000	-691.177	90.0	115.5	ROTATE
F006-H	7	-1302.598	60.000	-696.226	87.0	78.6	ROTATE
F006-S	7	-1302.355	60.000	-695.498	90.0	66.9	ROTATE
F007-H	7	-1302.380	60.000	-692.052	90.0	27.3	ROTATE
F007-S	7	-1302.387	60.000	-688.019	90.0	45.0	ROTATE
F008-H	7	-1302.353	60.000	-688.159	90.0	23.1	ROTATE
F008-S	7	-1302.583	60.000	-692.209	51.0	35.1	ROTATE
F009-H	7	-1302.563	60.000	-694.968	90.0	74.4	ROTATE
F009-S	7	-1302.468	60.000	-690.378	27.0	146.1	ROTATE
F010-H	7	-1303.093	60.000	-699.043	90.0	68.7	ROTATE
F010-S	7	-1302.447	60.000	-698.503	90.0	36.3	ROTATE
F011-H	7	-1302.508	60.000	-696.864	90.0	19.8	ROTATE
F011-S	7	-1302.507	60.000	-699.515	90.0	32.4	ROTATE
F012-H	7	-1302.721	60.000	-690.763	0.0	65.4	no
F012-S	7	-1302.448	60.000	-686.362	0.0	52.8	no
F013-H	7	-1302.477	60.000	-697.044	90.0	66.3	ROTATE
F013-S	7	-1303.497	60.000	-694.904	0.0	124.8	no
F014-H	7	-1302.313	60.000	-691.819	81.0	45.0	ROTATE
F014-S	7	-1302.328	60.000	-697.499	66.0	58.5	ROTATE
F015-H	7	-1302.520	60.000	-696.143	90.0	57.0	ROTATE
F015-S	7	-1302.609	60.000	-696.453	90.0	60.3	ROTATE
F016-H	7	-1302.532	60.000	-697.161	90.0	18.6	ROTATE
F016-S	7	-1302.881	60.000	-702.530	90.0	45.9	ROTATE
F017-H	7	-1302.448	60.000	-702.657	90.0	38.4	ROTATE
F017-S	7	-1302.754	60.000	-695.017	93.0	56.1	ROTATE
F018-H	7	-1302.488	60.000	-697.525	90.0	45.3	ROTATE
F018-S	7	-1302.404	60.000	-697.328	90.0	28.8	ROTATE
F019-H	7	-1302.544	60.000	-692.862	90.0	35.7	ROTATE
F019-S	7	-1303.043	60.000	-692.769	90.0	82.5	ROTATE
F020-H	7	-1302.448	60.000	-690.188	90.0	57.6	ROTATE
F020-S	7	-1302.743	60.000	-689.035	90.0	46.5	ROTATE
F021-H	7	-1302.363	60.000	-697.259	90.0	66.6	ROTATE
F021-S	7	-1302.875	60.000	-691.862	93.0	56.4	ROTATE
F022-H	7	-1302.409	60.000	-698.458	90.0	63.3	ROTATE
F022-S	7	-1303.088	60.000	-699.479	63.0	75.6	ROTATE
F023-H	7	-1302.808	60.000	-697.569	0.0	50.1	no
F023-S	7	-1303.029	60.000	-692.098	15.0	84.6	no
F024-H	7	-1302.906	60.000	-694.995	72.0	42.9	ROTATE
F024-S	7	-1302.251	60.000	-697.451	90.0	23.4	ROTATE
F025-H	7	-1302.426	60.000	-697.899	90.0	54.0	ROTATE
F025-S	7	-1302.734	60.000	-694.588	90.0	66.3	ROTATE
F026-H	7	-1302.892	60.000	-690.065	90.0	80.4	ROTATE
F026-S	7	-1302.758	60.000	-688.310	90.0	64.2	ROTATE
F027-H	7	-1302.451	60.000	-695.894	90.0	48.9	ROTATE
F027-S	7	-1302.962	60.000	-688.248	0.0	83.4	no
F028-H	7	-1303.500	60.000	-694.946	90.0	87.6	ROTATE
F028-S	7	-1302.824	60.000	-697.098	90.0	42.6	ROTATE
F029-H	7	-1302.636	60.000	-691.998	90.0	43.2	ROTATE
F029-S	7	-1302.617	60.000	-691.436	90.0	28.2	ROTATE
F030-H	7	-1302.372	60.000	-683.576	90.0	58.2	ROTATE
F030-S	7	-1302.736	60.000	-689.949	90.0	54.0	ROTATE
F031-H	7	-1302.771	60.000	-693.464	42.0	37.5	ROTATE
F031-S	7	-1302.695	60.000	-683.866	45.0	74.7	ROTATE
F032-H	7	-1302.991	60.000	-692.400	0.0	86.7	no
F032-S	7	-1302.879	60.000	-692.747	90.0	43.5	ROTATE
F033-H	7	-1303.082	60.000	-692.556	90.0	87.6	ROTATE

File	Room	X	Y	Z	Rotate	Speed	RESULT
F033-S	7	-1302.866	60.000	-692.544	0.0	118.2	no
F034-H	7	-1302.555	60.000	-699.031	3.0	72.3	no
F034-S	7	-1302.620	60.000	-702.376	39.0	75.9	ROTATE
F035-H	7	-1302.385	60.000	-687.519	90.0	33.9	ROTATE
F035-S	7	-1302.404	60.000	-693.537	90.0	37.5	ROTATE
F036-H	7	-1302.564	60.000	-682.993	90.0	29.1	ROTATE
F036-S	7	-1302.330	60.000	-690.687	0.0	18.3	no
F037-H	7	-1302.347	60.000	-697.996	90.0	51.9	ROTATE
F037-S	7	-1303.213	60.000	-692.275	90.0	78.6	ROTATE
F038-H	7	-1302.387	60.000	-699.895	90.0	66.3	ROTATE
F038-S	7	-1302.829	60.000	-699.421	90.0	42.9	ROTATE
F040-H	7	-1302.851	60.000	-693.354	90.0	45.3	ROTATE
F040-S	7	-1302.470	60.000	-693.070	90.0	43.2	ROTATE
F041-H	7	-1302.327	60.000	-698.095	0.0	13.8	no
F041-S	7	-1302.562	60.000	-698.125	0.0	31.2	no
F042-H	7	-1302.554	60.000	-701.939	90.0	21.0	ROTATE
F042-S	7	-1302.453	60.000	-698.332	0.0	26.7	no
F043-H	7	-1302.357	60.000	-693.735	0.0	19.5	no
F043-S	7	-1302.258	60.000	-696.535	12.0	42.3	no
H001-H	7	-1302.285	60.000	-701.336	0.0	18.3	no
H002-H	7	-1302.591	60.000	-696.658	0.0	36.3	no
H003-H	7	-1303.026	60.000	-695.025	3.0	63.6	no
I001-H	7	-1302.812	60.000	-699.723	90.0	60.0	ROTATE
I001-S	7	-1302.638	60.000	-700.140	90.0	30.0	ROTATE
P001-H	7	-1302.277	60.000	-692.994	90.0	53.1	ROTATE
P001-S	7	-1302.859	60.000	-689.654	90.0	65.4	ROTATE
P002-H	7	-1302.708	60.000	-700.073	90.0	57.0	ROTATE
P002-S	7	-1302.335	60.000	-698.115	90.0	41.7	ROTATE
P003-H	7	-1302.364	60.000	-705.284	90.0	11.4	ROTATE
P003-S	7	-1302.396	60.000	-700.577	90.0	12.6	ROTATE
P004-H	7	-1302.885	60.000	-692.642	90.0	50.1	ROTATE
P004-S	7	-1302.970	166.000	-703.156	0.0	59.7	m/b
P005-H	7	-1302.495	60.000	-692.936	90.0	16.5	ROTATE
P005-S	7	-1302.632	60.000	-696.053	72.0	27.0	ROTATE
P006-H	7	-1302.604	60.000	-694.699	0.0	67.8	no
P006-S	7	-1302.591	60.000	-697.811	0.0	47.7	no
P007-H	7	-1302.732	60.000	-698.714	90.0	33.0	ROTATE
P007-S	7	-1302.927	60.000	-687.158	90.0	43.5	ROTATE
P008-H	7	-1302.909	60.000	-703.070	0.0	67.5	no
P008-S	7	-1302.766	60.000	-704.497	0.0	66.3	no
P009-H	7	-1302.764	60.000	-688.657	0.0	72.6	no
P009-S	7	-1303.013	60.000	-698.841	0.0	133.5	no
P010-H	7	-1302.412	60.000	-694.597	90.0	60.6	ROTATE
P010-S	7	-1303.038	60.000	-704.687	0.0	60.9	no

Task Room 8 Reduced Data

File	Room	X	Y	Z	Rotate	Speed	RESULT
A001-H	8	-1222.322	60.000	-222.158	0.0	40.5	not
A002-H	8	-1237.414	60.000	-222.360	0.0	69.9	not
A003-H	8	-1237.935	60.000	-222.105	0.0	62.4	not
A004-H	8	-1108.885	60.000	-221.753	0.0	69.6	CATCH
A005-H	8	-1222.695	60.000	-222.272	0.0	58.5	not
B001-H	8	-1125.904	60.000	-221.509	0.0	17.1	CATCH
B001-S	8	-1230.500	60.000	-221.964	0.0	46.8	not
B002-H	8	-1114.823	60.000	-221.852	0.0	23.7	CATCH
B002-S	8	-1232.286	60.000	-222.294	0.0	84.9	not
B003-H	8	-1104.294	60.000	-221.894	0.0	49.2	CATCH
B003-S	8	-1236.751	60.000	-221.951	0.0	58.5	not
B004-H	8	-1109.724	60.000	-222.652	0.0	69.9	CATCH

B004-S	8	-1234.119	60.000	-221.890	0.0	94.8	not
B005-H	8	-1110.643	60.000	-221.506	90.0	24.6	CATCH
B005-S	8	-1189.553	60.000	-221.755	0.0	16.5	not
F001-H	8	-1232.963	60.000	-221.677	0.0	36.3	not
F001-S	8	-1234.633	60.000	-222.083	0.0	43.5	not
F002-H	8	-1107.128	60.000	-221.993	0.0	83.1	CATCH
F002-S	8	-1124.218	60.000	-221.521	0.0	71.4	CATCH
F003-H	8	-1114.487	60.000	-221.568	0.0	63.0	CATCH
F003-S	8	-1134.246	60.000	-222.127	0.0	143.1	CATCH
F004-H	8	-1127.115	60.000	-221.977	0.0	81.6	CATCH
F004-S	8	-1104.123	60.000	-222.087	0.0	41.4	CATCH
F005-H	8	-1123.300	60.000	-221.675	0.0	113.4	CATCH
F005-S	8	-1128.503	80.000	-222.571	0.0	119.7	CATCH
F006-H	8	-1115.859	60.000	-221.626	0.0	84.6	CATCH
F006-S	8	-1228.468	60.000	-222.711	0.0	83.4	not
F007-H	8	-1229.778	60.000	-221.971	0.0	55.2	not
F007-S	8	-1229.450	60.000	-222.071	0.0	65.4	not
F008-H	8	-1240.681	60.000	-221.755	0.0	34.5	not
F008-S	8	-1234.828	60.000	-222.144	0.0	42.6	not
F009-H	8	-1227.534	60.000	-221.763	90.0	59.7	not
F009-S	8	-1226.720	60.000	-221.707	45.0	149.4	not
F010-H	8	-1225.429	60.000	-221.796	0.0	87.0	not
F010-S	8	-1126.281	60.000	-221.737	0.0	48.6	CATCH
F011-H	8	-1230.659	60.000	-221.865	0.0	23.4	not
F011-S	8	-1232.104	60.000	-222.222	0.0	48.3	not
F012-H	8	-1231.782	60.000	-221.607	0.0	75.6	not
F012-S	8	-1229.060	60.000	-222.131	0.0	54.3	not
F013-H	8	-1224.597	60.000	-222.482	0.0	77.1	not
F013-S	8	-1227.180	60.000	-222.887	0.0	111.3	not
F014-H	8	-1231.017	60.000	-222.044	0.0	71.4	not
F014-S	8	-1226.003	60.000	-221.654	0.0	60.9	not
F015-H	8	-1236.898	60.000	-222.109	0.0	36.9	not
F015-S	8	-1231.898	60.000	-221.769	0.0	67.5	not
F016-H	8	-1106.534	60.000	-221.778	90.0	17.1	CATCH
F016-S	8	-1122.342	60.000	-222.581	90.0	70.8	CATCH
F017-H	8	-1227.276	60.000	-221.982	0.0	38.4	not
F017-S	8	-1227.994	60.000	-222.072	0.0	51.6	not
F018-H	8	-1225.619	60.000	-221.612	0.0	50.4	not
F018-S	8	-1226.025	60.000	-221.995	0.0	40.5	not
F019-H	8	-1231.891	60.000	-222.148	90.0	58.5	not
F019-S	8	-1232.199	60.000	-221.799	0.0	92.4	not
F020-H	8	-1231.399	60.000	-221.871	0.0	70.5	not
F020-S	8	-1235.734	60.000	-221.832	0.0	51.9	not
F021-H	8	-1224.602	60.000	-222.015	0.0	58.8	not
F021-S	8	-1233.768	60.000	-222.295	0.0	83.1	not
F022-H	8	-1114.582	60.000	-222.216	0.0	78.0	CATCH
F022-S	8	-1221.829	60.000	-221.804	0.0	63.6	not
F023-H	8	-1232.122	60.000	-221.639	0.0	36.6	not
F023-S	8	-1226.170	60.000	-222.316	0.0	81.9	not
F024-H	8	-1227.912	60.000	-222.219	90.0	44.4	not
F024-S	8	-1228.462	60.000	-221.722	0.0	25.8	not
F025-H	8	-1232.206	60.000	-221.971	0.0	60.6	not
F025-S	8	-1236.593	60.000	-221.529	0.0	64.5	not
F026-H	8	-1229.287	60.000	-222.002	0.0	59.7	not
F026-S	8	-1237.517	60.000	-221.540	0.0	63.9	not
F027-H	8	-1228.134	60.000	-222.049	0.0	75.3	not
F027-S	8	-1227.929	60.000	-221.635	0.0	97.8	not
F028-H	8	-1225.830	60.000	-221.687	0.0	62.7	not
F028-S	8	-1232.440	60.000	-221.979	0.0	104.1	not
F029-H	8	-1226.443	60.000	-222.229	0.0	67.5	not

File	Room	X	Y	Z	Rotate	Speed	RESULT
F029-S	8	-1239.917	60.000	-221.763	0.0	34.8	not
F030-H	8	-1233.717	60.000	-222.290	0.0	60.6	not
F030-S	8	-1232.720	60.000	-222.178	0.0	59.7	not
F031-H	8	-1228.801	60.000	-221.681	0.0	40.5	not
F031-S	8	-1229.314	60.000	-222.178	0.0	47.7	not
F032-H	8	-1227.243	60.000	-221.969	0.0	85.8	not
F032-S	8	-1225.659	60.000	-222.396	0.0	74.7	not
F033-H	8	-1223.164	60.000	-222.587	0.0	84.3	not
F033-S	8	-1216.124	60.000	-223.143	0.0	125.4	not
F034-H	8	-1230.210	60.000	-221.582	0.0	75.6	not
F034-S	8	-1233.165	60.000	-222.425	0.0	91.5	not
F035-H	8	-1234.782	60.000	-222.085	90.0	44.4	not
F035-S	8	-1231.470	60.000	-221.956	0.0	59.7	not
F036-H	8	-1231.400	60.000	-221.825	0.0	29.7	not
F036-S	8	-1229.233	60.000	-221.736	0.0	20.1	not
F037-H	8	-1228.427	60.000	-222.033	0.0	57.0	not
F037-S	8	-1228.938	60.000	-222.015	0.0	70.5	not
F038-H	8	-1205.407	60.000	-222.291	0.0	74.4	not
F038-S	8	-1198.293	60.000	-222.116	0.0	49.2	not
F040-H	8	-1225.564	60.000	-221.845	0.0	54.9	not
F040-S	8	-1232.721	60.000	-221.526	0.0	36.6	not
F041-H	8	-1102.758	60.000	-221.677	0.0	14.7	CATCH
F041-S	8	-1102.864	60.000	-221.848	0.0	21.3	CATCH
F042-H	8	-1227.092	60.000	-221.714	0.0	35.4	not
F042-S	8	-1229.351	60.000	-222.121	0.0	44.4	not
F043-H	8	-1233.970	60.000	-221.717	0.0	29.4	not
F043-S	8	-1236.783	60.000	-222.225	0.0	44.4	not
H001-H	8	-1228.337	60.000	-221.541	0.0	55.8	not
H002-H	8	-1228.252	60.000	-221.692	0.0	21.0	not
H003-H	8	-1227.286	60.000	-221.520	0.0	53.7	not
I001-H	8	-1227.235	60.000	-221.706	0.0	65.4	not
I001-S	8	-1227.575	60.000	-222.148	0.0	63.3	not
P001-H	8	-1220.750	60.000	-222.577	0.0	81.3	not
P001-S	8	-1232.298	60.000	-222.561	0.0	72.3	not
P002-H	8	-1231.289	60.000	-221.570	0.0	61.8	not
P002-S	8	-1240.823	60.000	-222.174	0.0	40.2	not
P003-H	8	-1192.135	60.000	-221.561	0.0	10.5	not
P003-S	8	-1203.645	60.000	-221.758	0.0	30.6	not
P004-H	8	-1225.416	60.000	-221.546	90.0	41.4	not
P004-S	8	-1205.090	60.000	-222.059	0.0	49.2	not
P005-H	8	-1229.771	60.000	-221.618	90.0	49.2	not
P005-S	8	-1223.905	60.000	-221.626	90.0	20.7	not
P006-H	8	-1231.797	60.000	-221.744	0.0	29.4	not
P006-S	8	-1240.880	60.000	-221.513	0.0	88.5	not
P007-H	8	-1233.342	60.000	-221.804	0.0	30.3	not
P007-S	8	-1239.963	60.000	-221.951	0.0	35.1	not
P008-H	8	-1103.411	60.000	-222.104	0.0	62.4	CATCH
P008-S	8	-1180.223	60.000	-221.652	18.0	46.5	not
P009-H	8	-1226.964	60.000	-222.337	0.0	77.7	not
P009-S	8	-1241.475	60.000	-222.883	0.0	139.2	not
P010-H	8	-1110.611	60.000	-221.873	0.0	61.8	CATCH
P010-S	8	-1192.090	60.000	-221.577	0.0	41.7	not

Task Room 9 Reduced Data

File	Room	X	Y	Z	Rotate	Speed	RESULT
A001-H	9	-713.421	60.000	-31.683	0.0	47.1	no
A002-H	9	-714.268	60.000	-32.535	0.0	94.5	no
A003-H	9	-713.307	60.000	-26.338	0.0	45.3	no

A004-H	9	-713.442	60.000	-30.050	0.0	46.8	no
A005-H	9	-713.659	125.000	-116.670	0.0	68.1	FLY
B001-H	9	-712.976	60.000	-27.857	0.0	17.4	no
B001-S	9	-712.771	60.000	-23.528	0.0	22.2	no
B002-H	9	-713.538	60.000	-34.647	0.0	50.1	no
B002-S	9	-712.862	60.000	-15.344	0.0	76.5	no
B003-H	9	-713.446	60.000	-28.665	0.0	58.8	no
B003-S	9	-712.937	60.000	-24.654	0.0	71.1	no
B004-H	9	-713.145	60.000	-33.085	0.0	50.4	no
B004-S	9	-714.291	125.000	-129.016	0.0	97.8	FLY
B005-H	9	-713.121	60.000	-37.704	90.0	27.3	m/b
B005-S	9	-713.240	60.000	-35.115	0.0	33.9	no
F001-H	9	-712.945	60.000	-27.814	0.0	25.8	no
F001-S	9	-713.018	60.000	-15.159	0.0	51.0	no
F002-H	9	-712.757	125.000	-131.850	0.0	86.4	FLY
F002-S	9	-713.238	60.000	-36.774	0.0	51.9	no
F003-H	9	-712.993	125.000	-134.107	0.0	83.4	FLY
F003-S	9	-714.922	125.000	-121.442	0.0	133.8	FLY
F004-H	9	-713.411	60.000	-39.952	0.0	80.1	no
F004-S	9	-713.572	60.000	-37.100	0.0	71.7	no
F005-H	9	-714.904	125.000	-140.604	0.0	150.0	FLY
F005-S	9	-712.883	125.000	-127.571	0.0	115.2	FLY
F006-H	9	-712.916	107.000	-139.820	0.0	83.1	FLY
F006-S	9	-713.601	60.000	-23.187	0.0	66.3	no
F007-H	9	-712.936	125.000	-126.980	0.0	65.7	FLY
F007-S	9	-713.094	60.000	-26.089	0.0	60.3	no
F008-H	9	-713.276	125.000	-122.856	0.0	32.1	FLY
F008-S	9	-712.861	125.000	-123.512	0.0	36.9	FLY
F009-H	9	-713.935	125.000	-132.924	0.0	80.4	FLY
F009-S	9	-715.072	60.000	-15.161	0.0	150.0	no
F010-H	9	-713.980	108.000	-135.022	18.0	95.7	FLY
F010-S	9	-713.570	60.000	-27.317	0.0	51.9	no
F011-H	9	-712.800	60.000	-35.156	0.0	33.0	no
F011-S	9	-713.399	60.000	-39.375	0.0	42.6	no
F012-H	9	-713.473	111.000	-121.356	0.0	75.9	FLY
F012-S	9	-713.117	125.000	-118.962	0.0	76.8	FLY
F013-H	9	-713.060	60.000	-25.021	0.0	79.2	no
F013-S	9	-713.672	60.000	-15.692	0.0	119.1	no
F014-H	9	-713.671	60.000	-30.650	0.0	65.4	no
F014-S	9	-713.375	125.000	-124.481	0.0	62.4	FLY
F015-H	9	-714.027	60.000	-33.605	0.0	81.9	no
F015-S	9	-713.114	125.000	-125.027	0.0	110.4	FLY
F016-H	9	-712.907	125.000	-125.551	0.0	27.3	FLY
F016-S	9	-712.758	125.000	-134.543	0.0	21.3	FLY
F017-H	9	-713.287	101.000	-136.388	0.0	48.0	FLY
F017-S	9	-713.470	125.000	-121.446	0.0	75.6	FLY
F018-H	9	-712.793	125.000	-128.357	0.0	53.1	FLY
F018-S	9	-713.064	125.000	-130.434	0.0	39.9	FLY
F019-H	9	-713.115	125.000	-135.168	0.0	76.2	FLY
F019-S	9	-712.849	125.000	-135.563	0.0	96.0	FLY
F020-H	9	-713.638	125.000	-120.567	0.0	69.6	FLY
F020-S	9	-713.329	125.000	-124.170	0.0	66.3	FLY
F021-H	9	-713.149	125.000	-130.581	0.0	70.2	FLY
F021-S	9	-712.888	125.000	-117.342	0.0	90.9	FLY
F022-H	9	-712.938	60.000	-28.485	0.0	79.5	no
F022-S	9	-713.165	114.000	-124.802	0.0	64.2	FLY
F023-H	9	-712.945	125.000	-113.504	0.0	44.1	FLY
F023-S	9	-713.787	125.000	-128.980	0.0	88.5	FLY
F024-H	9	-713.110	60.000	-15.250	0.0	42.0	no
F024-S	9	-712.760	60.000	-21.158	0.0	22.2	no

F025-H	9	-713.194	60.000	-24.055	0.0	57.3	no
F025-S	9	-713.613	125.000	-127.104	0.0	70.5	FLY
F026-H	9	-713.082	60.000	-26.398	0.0	79.8	no
F026-S	9	-714.002	60.000	-21.722	0.0	88.8	no
F027-H	9	-713.324	60.000	-30.939	0.0	74.1	no
F027-S	9	-713.802	125.000	-118.611	0.0	84.0	FLY
F028-H	9	-714.080	125.000	-129.503	0.0	84.9	FLY
F028-S	9	-713.781	60.000	-32.000	0.0	105.0	no
F029-H	9	-712.773	60.000	-29.758	0.0	65.7	no
F029-S	9	-712.904	60.000	-29.882	0.0	31.5	no
F030-H	9	-713.567	125.000	-131.594	0.0	71.1	FLY
F030-S	9	-712.836	125.000	-130.659	0.0	85.2	FLY
F031-H	9	-713.094	60.000	-25.974	0.0	28.2	no
F031-S	9	-713.636	125.000	-99.778	0.0	68.7	FLY
F032-H	9	-713.421	125.000	-136.236	0.0	90.3	FLY
F032-S	9	-713.647	60.000	-32.495	0.0	59.4	no
F033-H	9	-713.399	60.000	-22.561	0.0	93.3	no
F033-S	9	-713.895	100.000	-120.822	0.0	125.1	FLY
F034-H	9	-713.903	125.000	-129.768	0.0	94.2	FLY
F034-S	9	-713.509	60.000	-25.860	0.0	110.4	no
F035-H	9	-713.277	60.000	-21.373	90.0	35.1	m/b
F035-S	9	-713.171	60.000	-24.303	0.0	44.7	no
F036-H	9	-713.110	125.000	-125.119	0.0	41.4	FLY
F036-S	9	-713.078	125.000	-126.044	0.0	31.5	FLY
F037-H	9	-713.055	125.000	-133.050	0.0	62.7	FLY
F037-S	9	-713.815	60.000	-22.583	0.0	87.9	no
F038-H	9	-713.053	60.000	-130.972	0.0	59.4	no
F038-S	9	-712.776	60.000	-129.564	0.0	54.6	no
F040-H	9	-712.945	125.000	-121.110	0.0	46.2	FLY
F040-S	9	-712.892	125.000	-122.220	0.0	44.7	FLY
F041-H	9	-713.378	60.000	-134.623	0.0	43.2	no
F041-S	9	-713.288	60.000	-25.541	0.0	34.5	no
F042-H	9	-713.137	121.000	-119.506	0.0	51.3	FLY
F042-S	9	-713.263	60.000	-35.926	0.0	46.5	no
F043-H	9	-713.409	125.000	-134.791	0.0	40.5	FLY
F043-S	9	-713.004	125.000	-125.563	0.0	57.3	FLY
H001-H	9	-712.866	60.000	-22.483	0.0	56.4	no
H002-H	9	-713.162	58.000	-134.255	0.0	35.1	no
H003-H	9	-713.180	60.000	-27.483	0.0	65.4	no
I001-H	9	-713.382	87.000	-127.826	0.0	43.8	FLY
I001-S	9	-712.817	60.000	-118.648	0.0	50.7	no
P001-H	9	-713.068	180.000	-137.861	0.0	64.2	FLY
P001-S	9	-712.821	60.000	-28.273	0.0	60.3	no
P002-H	9	-712.921	60.000	-47.393	0.0	39.0	no
P002-S	9	-713.340	60.000	-36.014	0.0	39.9	no
P003-H	9	-712.904	60.000	-39.264	0.0	19.5	no
P003-S	9	-712.820	60.000	-16.205	0.0	16.2	no
P004-H	9	-713.297	250.000	-139.934	0.0	51.6	FLY
P004-S	9	-712.940	178.000	-119.820	0.0	39.9	FLY
P005-H	9	-713.098	194.000	-124.755	0.0	34.5	FLY
P005-S	9	-713.454	158.000	-122.544	0.0	55.5	FLY
P006-H	9	-713.740	60.000	-35.806	0.0	66.0	no
P006-S	9	-713.045	74.000	-116.439	0.0	49.2	FLY
P007-H	9	-713.164	60.000	-40.837	90.0	30.3	m/b
P007-S	9	-713.342	208.000	-133.118	0.0	48.9	FLY
P008-H	9	-712.897	60.000	-36.123	0.0	97.2	no
P008-S	9	-713.133	60.000	-39.492	0.0	77.7	no
P009-H	9	-712.997	212.000	-133.125	0.0	75.9	FLY
P009-S	9	-713.705	142.000	-123.805	0.0	149.7	FLY
P010-H	9	-713.138	148.000	-114.796	0.0	67.5	FLY

File	Room	X	Y	Z	Rotate	Speed	RESULT
P010-S	9	-713.390	60.000	-39.015	0.0	47.7	no

Task Room 10 Reduced Data

File	Room	X	Y	Z	Rotate	Speed	RESULT
A001-H	10	-593.740	60.000	-564.362	0.0	48.3	no
A002-H	10	-585.676	60.000	-563.805	0.0	87.0	no
A003-H	10	-582.015	60.000	-563.635	90.0	83.4	ROTATE
A004-H	10	-576.342	60.000	-563.356	0.0	82.5	no
A005-H	10	-584.217	60.000	-564.026	0.0	77.1	no
B001-H	10	-569.541	60.000	-564.484	0.0	14.1	no
B001-S	10	-587.383	60.000	-564.350	0.0	38.4	no
B002-H	10	-560.512	60.000	-563.644	69.0	63.6	ROTATE
B002-S	10	-585.833	60.000	-563.587	0.0	95.7	no
B003-H	10	-564.142	60.000	-563.787	90.0	56.1	ROTATE
B003-S	10	-588.496	60.000	-563.913	0.0	69.6	no
B004-H	10	-569.846	60.000	-563.816	0.0	50.1	no
B004-S	10	-587.629	60.000	-563.644	0.0	83.1	no
B005-H	10	-572.276	60.000	-564.411	90.0	31.5	ROTATE
B005-S	10	-584.942	60.000	-564.030	0.0	53.7	no
F001-H	10	-588.262	60.000	-564.484	0.0	43.5	no
F001-S	10	-586.971	60.000	-563.659	90.0	57.0	ROTATE
F002-H	10	-591.456	60.000	-564.091	84.0	89.4	ROTATE
F002-S	10	-586.142	60.000	-563.865	0.0	61.5	no
F003-H	10	-589.032	60.000	-564.048	0.0	66.6	no
F003-S	10	-589.428	60.000	-563.565	33.0	94.5	ROTATE
F004-H	10	-587.214	60.000	-563.573	0.0	91.5	no
F004-S	10	-585.600	60.000	-564.373	0.0	51.9	no
F005-H	10	-588.188	60.000	-563.931	0.0	54.0	no
F005-S	10	-582.601	60.000	-562.982	51.0	117.6	ROTATE
F006-H	10	-591.553	60.000	-563.159	0.0	86.4	no
F006-S	10	-580.861	60.000	-564.293	6.0	87.0	no
F007-H	10	-589.949	60.000	-563.549	0.0	60.6	no
F007-S	10	-589.463	60.000	-563.831	0.0	63.6	no
F008-H	10	-590.268	60.000	-564.027	0.0	36.6	no
F008-S	10	-591.185	60.000	-564.433	0.0	38.7	no
F009-H	10	-588.180	60.000	-563.482	90.0	64.5	ROTATE
F009-S	10	-590.910	60.000	-562.268	51.0	150.0	ROTATE
F010-H	10	-585.457	60.000	-563.709	90.0	110.7	ROTATE
F010-S	10	-584.298	60.000	-563.884	0.0	67.2	no
F011-H	10	-590.455	60.000	-563.830	0.0	41.4	no
F011-S	10	-586.821	60.000	-564.212	0.0	46.8	no
F012-H	10	-589.425	60.000	-564.308	0.0	88.5	no
F012-S	10	-585.433	60.000	-563.759	0.0	69.6	no
F013-H	10	-583.739	60.000	-563.045	0.0	93.3	no
F013-S	10	-591.149	60.000	-563.253	0.0	145.2	no
F014-H	10	-587.272	60.000	-564.242	0.0	61.8	no
F014-S	10	-586.002	60.000	-563.586	0.0	67.5	no
F015-H	10	-588.530	60.000	-563.996	0.0	80.7	no
F015-S	10	-582.929	60.000	-563.171	0.0	109.8	no
F016-H	10	-587.176	60.000	-564.194	45.0	32.4	ROTATE
F016-S	10	-588.382	60.000	-564.331	0.0	36.0	no
F017-H	10	-588.083	60.000	-564.116	90.0	47.7	ROTATE
F017-S	10	-585.748	60.000	-563.732	0.0	72.6	no
F018-H	10	-588.168	60.000	-564.277	0.0	37.5	no
F018-S	10	-586.196	60.000	-564.135	0.0	37.8	no
F019-H	10	-576.714	60.000	-564.008	0.0	41.4	no
F019-S	10	-588.247	60.000	-563.074	0.0	97.2	no
F020-H	10	-589.735	60.000	-563.662	0.0	71.1	no

F020-S	10	-587.765	60.000	-564.013	0.0	59.4	no
F021-H	10	-586.064	60.000	-563.343	0.0	85.5	no
F021-S	10	-584.687	60.000	-564.261	0.0	87.9	no
F022-H	10	-582.343	60.000	-563.162	90.0	80.7	ROTATE
F022-S	10	-585.336	60.000	-563.783	0.0	77.1	no
F023-H	10	-587.890	60.000	-564.379	0.0	43.8	no
F023-S	10	-585.200	60.000	-563.514	0.0	94.5	no
F024-H	10	-583.173	60.000	-563.876	90.0	54.6	ROTATE
F024-S	10	-584.754	60.000	-564.074	0.0	42.0	no
F025-H	10	-583.131	60.000	-564.074	0.0	56.4	no
F025-S	10	-589.597	60.000	-564.239	0.0	71.4	no
F026-H	10	-588.387	60.000	-563.622	90.0	95.1	ROTATE
F026-S	10	-587.209	60.000	-564.233	0.0	38.7	no
F027-H	10	-588.399	60.000	-564.438	0.0	67.8	no
F027-S	10	-583.986	60.000	-563.157	0.0	86.1	no
F028-H	10	-590.163	60.000	-563.338	90.0	129.6	ROTATE
F028-S	10	-586.270	60.000	-563.938	0.0	122.4	no
F029-H	10	-592.510	60.000	-563.356	0.0	73.5	no
F029-S	10	-589.594	60.000	-564.148	0.0	69.3	no
F030-H	10	-585.609	60.000	-563.130	90.0	90.0	ROTATE
F030-S	10	-583.090	60.000	-563.930	0.0	72.3	no
F031-H	10	-589.016	60.000	-564.215	0.0	37.8	no
F031-S	10	-586.462	60.000	-564.127	0.0	74.4	no
F032-H	10	-587.919	60.000	-563.903	90.0	93.6	ROTATE
F032-S	10	-587.081	60.000	-564.437	0.0	53.1	no
F033-H	10	-590.390	60.000	-563.525	0.0	148.5	no
F033-S	10	-585.507	60.000	-562.734	0.0	146.1	no
F034-H	10	-593.287	60.000	-563.124	0.0	104.4	no
F034-S	10	-591.871	60.000	-563.056	0.0	120.9	no
F035-H	10	-586.094	60.000	-564.373	90.0	63.0	ROTATE
F035-S	10	-589.746	60.000	-563.965	18.0	48.0	ROTATE
F036-H	10	-589.347	60.000	-563.956	0.0	53.4	no
F036-S	10	-587.507	60.000	-564.137	0.0	41.4	no
F037-H	10	-589.854	60.000	-564.454	0.0	81.0	no
F037-S	10	-588.808	60.000	-563.807	0.0	110.1	no
F038-H	10	-579.858	60.000	-564.141	57.0	57.9	ROTATE
F038-S	10	-587.523	60.000	-563.858	0.0	46.5	no
F040-H	10	-587.985	60.000	-563.967	0.0	51.6	no
F040-S	10	-583.958	60.000	-563.955	0.0	51.3	no
F041-H	10	-581.405	60.000	-564.421	0.0	32.1	no
F041-S	10	-583.327	60.000	-564.142	0.0	46.5	no
F042-H	10	-592.487	60.000	-563.617	0.0	57.6	no
F042-S	10	-589.150	60.000	-564.393	0.0	60.6	no
F043-H	10	-587.355	60.000	-563.958	0.0	34.8	no
F043-S	10	-588.536	60.000	-564.074	0.0	42.9	no
H001-H	10	-588.081	60.000	-564.479	0.0	39.6	no
H002-H	10	-590.653	60.000	-564.173	0.0	48.6	no
H003-H	10	-592.202	60.000	-563.918	0.0	71.7	no
I001-H	10	-581.935	60.000	-563.146	0.0	84.0	no
I001-S	10	-587.476	60.000	-564.069	0.0	70.5	no
P001-H	10	-589.005	60.000	-564.250	90.0	51.3	ROTATE
P001-S	10	-587.981	60.000	-564.434	0.0	51.3	no
P002-H	10	-588.443	60.000	-564.355	0.0	80.7	no
P002-S	10	-586.633	60.000	-564.087	0.0	57.9	no
P003-H	10	-591.523	60.000	-564.329	0.0	29.4	no
P003-S	10	-588.449	60.000	-564.341	0.0	30.9	no
P004-H	10	-589.400	60.000	-563.774	0.0	78.3	no
P004-S	10	-588.782	60.000	-564.196	0.0	42.3	no
P005-H	10	-589.962	60.000	-564.201	90.0	51.9	ROTATE
P005-S	10	-585.360	60.000	-564.351	90.0	62.4	ROTATE

169

File	Room	X	Y	Z	Rotate	Speed	RESULT
P006-H	10	-580.536	60.000	-564.351	0.0	40.2	no
P006-S	10	-590.254	60.000	-564.343	0.0	59.7	no
P007-H	10	-588.628	60.000	-564.150	0.0	26.1	no
P007-S	10	-587.662	60.000	-563.845	0.0	54.3	no
P008-H	10	-583.009	60.000	-563.882	0.0	134.1	no
P008-S	10	-586.262	60.000	-564.299	0.0	61.8	no
P009-H	10	-588.635	60.000	-563.565	0.0	84.9	no
P009-S	10	-581.004	60.000	-562.952	0.0	143.1	no
P010-H	10	-581.476	60.000	-564.426	0.0	72.9	no
P010-S	10	-586.972	60.000	-563.470	0.0	61.5	no

Task Room 11 Reduced Data

File	Room	X	Y	Z	Rotate	Speed	RESULT
A001-H	11	-123.941	60.000	-735.466	0.0	54.3	CATCH
A002-H	11	-123.399	60.000	-735.048	0.0	55.5	CATCH
A003-H	11	-123.666	60.000	-727.359	90.0	43.5	CATCH
A004-H	11	-124.046	60.000	-729.577	0.0	80.7	CATCH
A005-H	11	-124.016	60.000	-726.603	0.0	48.3	CATCH
B001-H	11	-123.282	60.000	-738.370	0.0	17.4	CATCH
B001-S	11	-123.345	60.000	-726.102	0.0	21.3	CATCH
B002-H	11	-124.106	60.000	-735.768	0.0	57.9	CATCH
B002-S	11	-124.911	60.000	-729.685	0.0	117.9	CATCH
B003-H	11	-123.717	60.000	-733.469	0.0	40.8	CATCH
B003-S	11	-123.829	60.000	-734.107	0.0	66.0	CATCH
B004-H	11	-123.441	60.000	-739.588	0.0	43.8	CATCH
B004-S	11	-123.660	60.000	-731.890	0.0	93.6	CATCH
B005-H	11	-123.298	60.000	-742.101	0.0	35.1	CATCH
B005-S	11	-123.670	60.000	-631.578	0.0	38.4	not
F001-H	11	-123.653	60.000	-735.470	0.0	29.4	CATCH
F001-S	11	-123.327	60.000	-734.622	0.0	61.5	CATCH
F002-H	11	-124.753	60.000	-734.947	0.0	112.2	CATCH
F002-S	11	-123.335	60.000	-727.334	0.0	65.1	CATCH
F003-H	11	-123.681	60.000	-728.470	0.0	65.4	CATCH
F003-S	11	-124.538	60.000	-723.084	0.0	111.3	CATCH
F004-H	11	-124.120	60.000	-729.021	0.0	64.8	CATCH
F004-S	11	-123.983	60.000	-731.174	0.0	81.0	CATCH
F005-H	11	-124.322	60.000	-727.926	0.0	87.3	CATCH
F005-S	11	-123.510	60.000	-727.972	0.0	110.1	CATCH
F006-H	11	-124.090	60.000	-735.204	0.0	93.3	CATCH
F006-S	11	-124.804	60.000	-741.313	0.0	102.9	CATCH
F007-H	11	-123.286	60.000	-724.796	90.0	46.2	CATCH
F007-S	11	-123.631	60.000	-726.128	0.0	65.1	CATCH
F008-H	11	-123.604	60.000	-733.889	0.0	29.1	CATCH
F008-S	11	-123.486	60.000	-728.102	0.0	51.6	CATCH
F009-H	11	-123.335	60.000	-730.159	90.0	65.1	CATCH
F009-S	11	-124.943	60.000	-704.807	24.0	127.2	CATCH
F010-H	11	-123.537	60.000	-736.337	0.0	85.5	CATCH
F010-S	11	-123.684	60.000	-730.063	0.0	66.3	CATCH
F011-H	11	-123.310	60.000	-732.574	0.0	25.2	CATCH
F011-S	11	-123.523	60.000	-615.007	0.0	42.6	not
F012-H	11	-123.553	60.000	-730.601	0.0	75.9	CATCH
F012-S	11	-123.609	60.000	-723.694	0.0	78.0	CATCH
F013-H	11	-124.882	60.000	-735.362	0.0	102.6	CATCH
F013-S	11	-125.391	60.000	-723.392	0.0	146.1	CATCH
F014-H	11	-124.071	60.000	-728.959	0.0	62.4	CATCH
F014-S	11	-123.707	60.000	-730.003	0.0	55.5	CATCH
F015-H	11	-123.668	60.000	-730.975	0.0	77.1	CATCH
F015-S	11	-123.778	60.000	-729.512	0.0	112.2	CATCH
F016-H	11	-123.495	60.000	-730.950	90.0	36.3	CATCH

F016-S	11	-123.484	60.000	-634.476	90.0	26.4	not
F017-H	11	-123.986	60.000	-734.902	0.0	48.3	CATCH
F017-S	11	-123.442	60.000	-726.903	0.0	47.7	CATCH
F018-H	11	-123.970	60.000	-728.243	0.0	51.0	CATCH
F018-S	11	-124.018	60.000	-727.154	0.0	55.5	CATCH
F019-H	11	-123.914	60.000	-732.767	0.0	63.6	CATCH
F019-S	11	-124.918	60.000	-730.441	0.0	117.9	CATCH
F020-H	11	-124.130	60.000	-730.587	0.0	70.5	CATCH
F020-S	11	-123.354	60.000	-726.948	0.0	68.4	CATCH
F021-H	11	-123.381	60.000	-729.940	0.0	86.4	CATCH
F021-S	11	-124.967	60.000	-731.067	0.0	118.5	CATCH
F022-H	11	-124.402	60.000	-733.671	0.0	74.4	CATCH
F022-S	11	-124.362	60.000	-730.659	0.0	78.0	CATCH
F023-H	11	-123.901	60.000	-735.129	0.0	47.7	CATCH
F023-S	11	-124.214	60.000	-738.848	0.0	97.8	CATCH
F024-H	11	-123.583	60.000	-736.801	0.0	48.3	CATCH
F024-S	11	-123.637	60.000	-730.027	0.0	25.2	CATCH
F025-H	11	-123.647	60.000	-732.129	0.0	40.2	CATCH
F025-S	11	-123.351	60.000	-731.548	0.0	81.3	CATCH
F026-H	11	-123.812	60.000	-735.964	0.0	99.6	CATCH
F026-S	11	-124.380	60.000	-732.117	0.0	75.3	CATCH
F027-H	11	-123.898	60.000	-727.982	0.0	58.2	CATCH
F027-S	11	-123.503	60.000	-729.089	0.0	79.5	CATCH
F028-H	11	-125.317	60.000	-747.580	0.0	138.9	CATCH
F028-S	11	-124.208	60.000	-724.997	0.0	148.2	CATCH
F029-H	11	-123.265	60.000	-735.714	0.0	69.6	CATCH
F029-S	11	-123.587	60.000	-732.289	0.0	37.5	CATCH
F030-H	11	-124.337	60.000	-729.809	0.0	85.8	CATCH
F030-S	11	-123.511	60.000	-726.450	0.0	87.3	CATCH
F031-H	11	-123.606	60.000	-624.242	0.0	26.7	not
F031-S	11	-123.505	60.000	-729.913	0.0	56.1	CATCH
F032-H	11	-123.819	60.000	-728.939	0.0	51.6	CATCH
F032-S	11	-123.930	60.000	-733.462	0.0	71.1	CATCH
F033-H	11	-123.943	60.000	-737.077	0.0	121.8	CATCH
F033-S	11	-125.243	60.000	-729.156	0.0	145.2	CATCH
F034-H	11	-124.586	60.000	-734.782	0.0	102.6	CATCH
F034-S	11	-123.893	60.000	-727.415	0.0	124.8	CATCH
F035-H	11	-123.951	60.000	-728.802	90.0	48.6	CATCH
F035-S	11	-123.774	60.000	-725.799	90.0	46.5	CATCH
F036-H	11	-123.736	60.000	-736.853	0.0	42.9	CATCH
F036-S	11	-123.722	60.000	-731.711	0.0	33.0	CATCH
F037-H	11	-124.118	60.000	-731.017	0.0	62.1	CATCH
F037-S	11	-124.816	60.000	-731.463	0.0	133.2	CATCH
F038-H	11	-123.387	60.000	-737.809	0.0	56.7	CATCH
F038-S	11	-123.989	60.000	-736.234	0.0	50.1	CATCH
F040-H	11	-123.861	60.000	-733.916	0.0	53.1	CATCH
F040-S	11	-123.485	60.000	-731.325	0.0	42.6	CATCH
F041-H	11	-123.296	60.000	-733.825	0.0	12.9	CATCH
F041-S	11	-123.706	60.000	-731.511	0.0	33.0	CATCH
F042-H	11	-123.839	60.000	-740.398	0.0	54.0	CATCH
F042-S	11	-123.351	60.000	-734.413	0.0	60.6	CATCH
F043-H	11	-123.547	60.000	-728.883	0.0	42.9	CATCH
F043-S	11	-123.274	60.000	-729.556	0.0	56.1	CATCH
H001-H	11	-124.011	60.000	-736.214	0.0	53.1	CATCH
H002-H	11	-123.504	60.000	-739.725	0.0	32.1	CATCH
H003-H	11	-123.727	60.000	-729.268	0.0	67.2	CATCH
I001-H	11	-123.459	60.000	-731.159	0.0	79.8	CATCH
I001-S	11	-123.641	60.000	-734.269	0.0	46.8	CATCH
P001-H	11	-124.191	60.000	-623.002	0.0	60.9	not
P001-S	11	-123.538	60.000	-620.426	0.0	54.0	not

File	Room	X	Y	Z	Rotate	Speed	RESULT
P002-H	11	-124.232	60.000	-729.292	0.0	72.3	CATCH
P002-S	11	-123.288	60.000	-732.465	0.0	78.3	CATCH
P003-H	11	-123.263	60.000	-738.636	0.0	16.8	CATCH
P003-S	11	-123.322	60.000	-616.481	0.0	23.4	not
P004-H	11	-124.042	60.000	-749.716	0.0	51.3	CATCH
P004-S	11	-124.094	60.000	-731.709	0.0	55.8	CATCH
P005-H	11	-123.928	60.000	-732.765	90.0	42.9	CATCH
P005-S	11	-123.719	60.000	-730.981	90.0	46.2	CATCH
P006-H	11	-123.256	60.000	-746.357	0.0	13.2	CATCH
P006-S	11	-123.765	60.000	-616.916	0.0	63.0	not
P007-H	11	-123.344	60.000	-733.026	0.0	24.6	CATCH
P007-S	11	-123.624	60.000	-729.615	0.0	27.0	CATCH
P008-H	11	-123.384	60.000	-737.737	0.0	80.7	CATCH
P008-S	11	-123.607	60.000	-737.902	0.0	100.5	CATCH
P009-H	11	-124.393	60.000	-727.585	0.0	80.1	CATCH
P009-S	11	-125.095	60.000	-726.831	0.0	129.9	CATCH
P010-H	11	-123.350	60.000	-724.152	0.0	73.5	CATCH
P010-S	11	-123.495	60.000	-727.072	0.0	54.3	CATCH

Task Room 12 Reduced Data

File	Room	X	Y	Z	Rotate	Speed	RESULT
A001-H	12	-63.447	60.000	-221.862	0.0	61.2	no
A002-H	12	-41.235	60.000	-222.250	0.0	77.7	no
A003-H	12	25.280	125.000	-221.899	0.0	75.6	FLY
A004-H	12	-49.962	60.000	-221.680	0.0	83.7	no
A005-H	12	-49.070	60.000	-222.086	0.0	60.6	no
B001-H	12	-51.791	60.000	-221.683	0.0	21.6	no
B001-S	12	-52.388	60.000	-221.665	0.0	25.8	no
B002-H	12	53.075	125.000	-221.992	30.0	49.2	FLY
B002-S	12	-63.472	60.000	-222.128	0.0	110.1	no
B003-H	12	42.143	125.000	-221.807	0.0	48.6	FLY
B003-S	12	-49.172	60.000	-221.529	0.0	70.2	no
B004-H	12	53.190	125.000	-221.941	0.0	47.4	FLY
B004-S	12	-44.493	60.000	-223.100	0.0	98.7	no
B005-H	12	-33.621	60.000	-221.857	0.0	32.7	no
B005-S	12	-43.363	60.000	-221.699	0.0	49.2	no
F001-H	12	41.856	125.000	-221.732	0.0	53.1	FLY
F001-S	12	51.088	125.000	-222.062	0.0	90.6	FLY
F002-H	12	46.178	87.000	-222.830	0.0	107.4	FLY
F002-S	12	43.910	125.000	-222.643	0.0	71.4	FLY
F003-H	12	48.289	125.000	-221.579	0.0	88.8	FLY
F003-S	12	32.735	125.000	-222.527	0.0	116.7	FLY
F004-H	12	-47.895	60.000	-222.353	0.0	86.7	no
F004-S	12	-53.251	60.000	-222.392	0.0	101.1	no
F005-H	12	43.336	125.000	-221.963	0.0	147.6	FLY
F005-S	12	45.192	125.000	-223.018	0.0	132.0	FLY
F006-H	12	-43.412	60.000	-222.330	0.0	82.2	no
F006-S	12	-51.649	60.000	-221.639	0.0	58.8	no
F007-H	12	40.613	125.000	-222.305	0.0	52.5	FLY
F007-S	12	-54.894	60.000	-221.599	0.0	54.0	no
F008-H	12	39.100	125.000	-221.959	0.0	56.4	FLY
F008-S	12	-58.639	60.000	-221.821	0.0	40.2	no
F009-H	12	51.159	125.000	-221.713	0.0	94.5	FLY
F009-S	12	42.648	108.000	-221.574	0.0	150.0	FLY
F010-H	12	40.875	125.000	-222.161	0.0	79.2	FLY
F010-S	12	40.104	125.000	-221.963	0.0	65.7	FLY
F011-H	12	-52.229	60.000	-221.873	0.0	33.3	no
F011-S	12	-54.754	60.000	-222.221	0.0	56.4	no
F012-H	12	-46.399	60.000	-222.478	0.0	81.3	no

F012-S	12	-59.236	60.000	-221.576	0.0	79.5	no
F013-H	12	-38.470	60.000	-222.490	0.0	93.0	no
F013-S	12	-47.744	60.000	-222.772	0.0	150.0	no
F014-H	12	37.325	125.000	-222.056	0.0	52.8	FLY
F014-S	12	-41.922	60.000	-222.057	0.0	51.9	no
F015-H	12	-52.331	60.000	-221.502	0.0	64.5	no
F015-S	12	-56.206	60.000	-223.267	0.0	123.6	no
F016-H	12	-52.962	60.000	-221.601	90.0	17.4	m/b
F016-S	12	30.931	125.000	-221.547	0.0	25.5	FLY
F017-H	12	48.734	125.000	-221.633	0.0	45.6	FLY
F017-S	12	-50.670	60.000	-222.073	0.0	57.9	no
F018-H	12	43.163	125.000	-221.716	0.0	61.2	FLY
F018-S	12	-50.831	60.000	-221.546	0.0	49.5	no
F019-H	12	58.063	125.000	-221.883	0.0	72.9	FLY
F019-S	12	66.420	125.000	-222.637	0.0	120.3	FLY
F020-H	12	32.939	125.000	-221.802	0.0	71.1	FLY
F020-S	12	-61.512	60.000	-221.682	0.0	79.5	no
F021-H	12	45.503	125.000	-221.529	0.0	117.3	FLY
F021-S	12	-61.055	60.000	-223.419	0.0	121.5	no
F022-H	12	-45.396	60.000	-222.534	0.0	75.6	no
F022-S	12	-50.046	60.000	-222.743	0.0	80.7	no
F023-H	12	46.271	125.000	-221.980	0.0	43.5	FLY
F023-S	12	-42.425	60.000	-221.528	0.0	82.5	no
F024-H	12	-45.898	60.000	-221.766	90.0	49.2	m/b
F024-S	12	-55.263	60.000	-221.674	0.0	50.4	no
F025-H	12	48.883	125.000	-221.604	0.0	48.3	FLY
F025-S	12	-50.433	60.000	-222.226	0.0	71.7	no
F026-H	12	-56.813	60.000	-222.805	0.0	101.1	no
F026-S	12	-60.714	60.000	-221.613	0.0	69.0	no
F027-H	12	46.701	125.000	-222.350	0.0	56.4	FLY
F027-S	12	-30.665	60.000	-222.141	0.0	87.0	no
F028-H	12	-35.924	60.000	-222.540	90.0	69.6	m/b
F028-S	12	-46.481	60.000	-222.268	0.0	131.7	no
F029-H	12	43.596	125.000	-221.901	0.0	60.9	FLY
F029-S	12	-58.731	60.000	-221.903	0.0	25.5	no
F030-H	12	-29.026	60.000	-221.782	0.0	22.5	no
F030-S	12	-55.933	60.000	-222.423	0.0	76.5	no
F031-H	12	-53.720	60.000	-221.976	0.0	35.7	no
F031-S	12	-52.614	60.000	-222.049	0.0	69.3	no
F032-H	12	47.722	125.000	-221.897	0.0	72.9	FLY
F032-S	12	-47.934	60.000	-222.257	0.0	63.6	no
F033-H	12	-54.968	60.000	-221.766	0.0	130.2	no
F033-S	12	42.057	102.000	-221.983	0.0	150.0	FLY
F034-H	12	-49.449	60.000	-222.535	0.0	109.2	no
F034-S	12	-55.113	60.000	-223.262	0.0	123.3	no
F035-H	12	-47.254	60.000	-221.948	90.0	31.2	m/b
F035-S	12	-54.976	60.000	-222.130	90.0	44.4	m/b
F036-H	12	47.485	125.000	-221.651	0.0	37.2	FLY
F036-S	12	-50.428	60.000	-221.720	0.0	21.3	no
F037-H	12	40.850	125.000	-221.769	0.0	73.2	FLY
F037-S	12	-57.767	60.000	-221.968	0.0	112.2	no
F038-H	12	52.111	90.000	-222.763	0.0	103.5	FLY
F038-S	12	-35.296	60.000	-221.993	0.0	45.3	no
F040-H	12	42.491	125.000	-221.956	0.0	58.8	FLY
F040-S	12	-61.386	60.000	-221.956	0.0	51.3	no
F041-H	12	69.412	60.000	-221.516	0.0	68.7	no
F041-S	12	-47.743	60.000	-221.713	0.0	20.7	no
F042-H	12	-45.345	60.000	-221.925	90.0	44.1	m/b
F042-S	12	-53.994	60.000	-221.713	0.0	66.0	no
F043-H	12	31.125	125.000	-222.158	0.0	52.5	FLY

File	Room	X	Y	Z	Rotate	Speed	RESULT
F043-S	12	-53.686	60.000	-221.917	0.0	50.7	no
H001-H	12	-54.536	60.000	-222.525	0.0	77.7	no
H002-H	12	40.814	87.000	-221.516	0.0	33.9	FLY
H003-H	12	-49.562	60.000	-222.206	0.0	62.1	no
I001-H	12	47.589	125.000	-221.838	0.0	41.7	FLY
I001-S	12	-53.998	60.000	-221.839	0.0	60.0	no
P001-H	12	-35.431	60.000	-222.889	0.0	93.0	no
P001-S	12	-42.938	60.000	-222.269	0.0	70.2	no
P002-H	12	-45.997	60.000	-222.258	0.0	62.1	no
P002-S	12	-52.619	60.000	-221.572	0.0	90.3	no
P003-H	12	-25.452	60.000	-221.501	0.0	11.1	no
P003-S	12	-46.289	60.000	-221.670	0.0	28.8	no
P004-H	12	54.430	158.000	-221.918	0.0	58.8	FLY
P004-S	12	-49.644	60.000	-221.945	0.0	35.1	no
P005-H	12	-47.525	60.000	-221.801	9.0	45.9	m/b
P005-S	12	45.327	138.000	-221.890	0.0	74.1	FLY
P006-H	12	-51.820	60.000	-221.511	0.0	64.8	no
P006-S	12	24.458	148.000	-221.601	0.0	40.5	FLY
P007-H	12	-45.839	60.000	-222.196	0.0	42.6	no
P007-S	12	43.900	250.000	-221.884	0.0	32.1	FLY
P008-H	12	-48.879	60.000	-222.073	0.0	72.3	no
P008-S	12	-47.607	60.000	-222.290	0.0	58.5	no
P009-H	12	-53.033	60.000	-222.668	0.0	87.3	no
P009-S	12	-48.000	60.000	-222.449	0.0	149.7	no
P010-H	12	-36.143	60.000	-221.542	0.0	74.1	no
P010-S	12	-40.722	60.000	-222.217	0.0	51.0	no

Task Room 13 Reduced Data

File	Room	X	Y	Z	Rotate	Speed	RESULT
A001-H	13	465.552	60.000	-97.818	90.0	54.0	ROTATE
A002-H	13	466.159	60.000	-98.605	90.0	93.0	ROTATE
A003-H	13	465.986	60.000	19.700	0.0	93.9	no
A004-H	13	466.044	60.000	-98.015	0.0	84.3	no
A005-H	13	465.160	60.000	-99.774	90.0	80.4	ROTATE
B001-H	13	466.175	60.000	-109.019	0.0	10.8	no
B001-S	13	466.048	60.000	-85.018	0.0	30.6	no
B002-H	13	465.706	60.000	-108.746	54.0	55.5	ROTATE
B002-S	13	466.214	60.000	-77.950	0.0	63.0	no
B003-H	13	466.097	60.000	-104.858	0.0	48.9	no
B003-S	13	465.818	60.000	-80.472	0.0	70.2	no
B004-H	13	465.558	60.000	-103.805	0.0	44.1	no
B004-S	13	466.111	60.000	-83.293	0.0	97.8	no
B005-H	13	465.983	60.000	-111.002	0.0	26.1	no
B005-S	13	466.055	60.000	-86.041	0.0	53.4	no
F001-H	13	465.821	60.000	-83.129	0.0	27.6	no
F001-S	13	465.915	60.000	-84.825	0.0	32.1	no
F002-H	13	464.331	60.000	-74.948	0.0	118.8	no
F002-S	13	465.422	60.000	-87.323	90.0	72.6	ROTATE
F003-H	13	465.347	60.000	-89.867	0.0	76.5	no
F003-S	13	464.365	60.000	-82.767	90.0	111.3	ROTATE
F004-H	13	465.231	60.000	-78.041	0.0	92.1	no
F004-S	13	465.201	60.000	-86.083	0.0	69.9	no
F005-H	13	465.347	60.000	-83.588	90.0	63.6	ROTATE
F005-S	13	465.815	60.000	-81.094	0.0	127.2	no
F006-H	13	466.234	60.000	-84.964	0.0	93.9	no
F006-S	13	465.974	60.000	-83.382	0.0	64.8	no
F007-H	13	465.788	60.000	-83.862	90.0	51.9	ROTATE
F007-S	13	466.012	60.000	-84.436	90.0	69.0	ROTATE
F008-H	13	465.767	60.000	-83.432	0.0	29.4	no

F008-S	13	465.988	60.000	-83.763	0.0	36.0	no
F009-H	13	465.594	60.000	-95.796	90.0	75.0	ROTATE
F009-S	13	466.039	60.000	-85.152	42.0	150.0	ROTATE
F010-H	13	465.623	60.000	-88.587	90.0	82.5	ROTATE
F010-S	13	466.009	60.000	-83.444	0.0	82.5	no
F011-H	13	465.881	60.000	-83.783	0.0	27.0	no
F011-S	13	465.470	60.000	-81.786	0.0	58.2	no
F012-H	13	464.897	60.000	-84.919	0.0	109.8	no
F012-S	13	464.701	60.000	-84.243	0.0	103.5	no
F013-H	13	464.838	60.000	-69.909	0.0	94.5	no
F013-S	13	465.392	60.000	-69.010	0.0	150.0	no
F014-H	13	465.970	60.000	-89.576	0.0	70.2	no
F014-S	13	464.513	60.000	-91.468	0.0	113.4	no
F015-H	13	466.118	60.000	-84.092	0.0	73.2	no
F015-S	13	465.522	60.000	-80.509	0.0	125.7	no
F016-H	13	466.063	60.000	-81.797	90.0	22.8	ROTATE
F016-S	13	466.080	60.000	-85.229	90.0	22.2	ROTATE
F017-H	13	465.460	60.000	-85.114	90.0	48.0	ROTATE
F017-S	13	465.811	60.000	-85.209	0.0	44.1	no
F018-H	13	465.719	60.000	-87.485	90.0	44.1	ROTATE
F018-S	13	466.152	60.000	-81.749	0.0	57.0	no
F019-H	13	466.207	60.000	-86.871	90.0	41.7	ROTATE
F019-S	13	465.763	60.000	-80.588	0.0	67.8	no
F020-H	13	465.124	60.000	-87.962	90.0	73.2	ROTATE
F020-S	13	465.656	60.000	-81.869	0.0	78.6	no
F021-H	13	465.193	60.000	-82.056	0.0	110.7	no
F021-S	13	465.975	60.000	-87.056	0.0	108.0	no
F022-H	13	465.088	60.000	-87.171	0.0	73.5	no
F022-S	13	465.466	60.000	-86.270	0.0	59.4	no
F023-H	13	465.852	60.000	-85.296	0.0	42.9	no
F023-S	13	465.464	60.000	-84.169	0.0	94.5	no
F024-H	13	465.690	60.000	-84.330	90.0	44.7	ROTATE
F024-S	13	466.110	60.000	-82.280	0.0	46.8	no
F025-H	13	466.048	60.000	-97.203	0.0	66.0	no
F025-S	13	465.345	60.000	-83.655	0.0	80.1	no
F026-H	13	466.185	60.000	-81.335	0.0	102.6	no
F026-S	13	465.188	60.000	-82.812	0.0	75.0	no
F027-H	13	465.746	60.000	-86.382	0.0	49.8	no
F027-S	13	464.804	60.000	-87.679	0.0	119.7	no
F028-H	13	465.462	60.000	-84.050	90.0	92.1	ROTATE
F028-S	13	464.267	60.000	-83.599	0.0	149.7	no
F029-H	13	465.880	60.000	-85.014	90.0	58.5	ROTATE
F029-S	13	466.130	60.000	-82.671	0.0	47.4	no
F030-H	13	466.034	60.000	-88.311	0.0	57.6	no
F030-S	13	465.593	60.000	-85.423	0.0	81.0	no
F031-H	13	465.724	60.000	-84.316	0.0	56.4	no
F031-S	13	465.144	60.000	-84.325	0.0	80.1	no
F032-H	13	464.963	60.000	-87.070	90.0	81.3	ROTATE
F032-S	13	465.647	60.000	-86.731	0.0	85.5	no
F033-H	13	465.292	60.000	-81.937	0.0	127.5	no
F033-S	13	464.640	60.000	-78.784	0.0	146.1	no
F034-H	13	466.104	60.000	-85.228	0.0	115.2	no
F034-S	13	466.051	60.000	-80.712	0.0	129.3	no
F035-H	13	466.145	60.000	-82.885	90.0	59.1	ROTATE
F035-S	13	465.767	60.000	-83.781	90.0	58.5	ROTATE
F036-H	13	465.972	60.000	-86.289	0.0	33.3	no
F036-S	13	465.975	60.000	-82.199	0.0	27.9	no
F037-H	13	465.105	60.000	-81.896	0.0	82.5	no
F037-S	13	465.525	60.000	-86.205	0.0	126.9	no
F038-H	13	466.028	60.000	-88.526	90.0	52.2	ROTATE

File	Room	X	Y	Z	Rotate	Speed	RESULT
F038-S	13	465.712	60.000	-85.743	0.0	58.5	no
F040-H	13	466.065	60.000	-85.016	0.0	40.8	no
F040-S	13	465.627	60.000	-79.745	0.0	45.9	no
F041-H	13	466.131	60.000	-89.958	0.0	38.1	no
F041-S	13	466.217	60.000	-84.486	0.0	15.6	no
F042-H	13	465.971	60.000	-97.393	90.0	51.3	ROTATE
F042-S	13	466.009	60.000	-83.594	0.0	65.1	no
F043-H	13	465.911	60.000	-83.628	0.0	54.3	no
F043-S	13	465.562	60.000	-87.264	0.0	58.8	no
H001-H	13	466.033	60.000	-92.354	0.0	56.7	no
H002-H	13	465.711	60.000	-100.103	0.0	42.3	no
H003-H	13	465.974	60.000	-89.432	0.0	81.9	no
I001-H	13	465.888	60.000	-83.533	18.0	54.9	ROTATE
I001-S	13	464.860	60.000	-83.110	0.0	86.4	no
P001-H	13	465.985	60.000	-90.931	90.0	63.9	ROTATE
P001-S	13	465.161	60.000	-82.167	0.0	85.2	no
P002-H	13	465.955	60.000	-100.134	0.0	55.2	no
P002-S	13	466.097	60.000	-87.360	0.0	91.5	no
P003-H	13	466.168	60.000	-91.161	0.0	21.6	no
P003-S	13	465.943	60.000	-80.700	0.0	27.6	no
P004-H	13	465.669	60.000	-89.568	0.0	48.9	no
P004-S	13	464.815	60.000	-84.858	0.0	89.7	no
P005-H	13	465.880	60.000	-85.095	90.0	24.0	ROTATE
P005-S	13	466.095	60.000	-81.893	90.0	64.2	ROTATE
P006-H	13	465.636	60.000	-96.062	0.0	69.6	no
P006-S	13	466.013	60.000	-83.692	0.0	36.6	no
P007-H	13	465.959	60.000	-93.276	0.0	19.5	no
P007-S	13	465.958	60.000	-85.830	0.0	40.8	no
P008-H	13	465.681	60.000	-94.550	0.0	62.4	no
P008-S	13	466.071	60.000	-92.190	0.0	75.3	no
P009-H	13	466.049	60.000	-94.176	0.0	78.9	no
P009-S	13	464.559	60.000	-88.280	0.0	145.2	no
P010-H	13	465.980	60.000	-75.844	0.0	82.8	no
P010-S	13	465.562	60.000	-82.154	0.0	65.4	no

Task Room 14 Reduced Data

File	Room	X	Y	Z	Rotate	Speed	RESULT
A001-H	14	650.050	60.000	-564.313	0.0	39.0	not
A002-H	14	651.668	60.000	-564.428	0.0	40.5	not
A003-H	14	651.133	60.000	-563.673	90.0	56.7	not
A004-H	14	549.797	60.000	-563.367	0.0	81.0	CATCH
A005-H	14	650.699	60.000	-564.353	0.0	32.1	not
B001-H	14	536.980	60.000	-564.406	0.0	18.9	CATCH
B001-S	14	656.269	60.000	-564.309	0.0	35.4	not
B002-H	14	545.104	60.000	-564.313	90.0	36.6	CATCH
B002-S	14	668.314	60.000	-564.403	0.0	54.6	not
B003-H	14	650.589	60.000	-563.794	0.0	44.4	not
B003-S	14	653.045	60.000	-563.924	0.0	63.3	not
B004-H	14	540.252	60.000	-563.861	0.0	58.8	CATCH
B004-S	14	656.726	60.000	-563.889	0.0	99.9	not
B005-H	14	638.564	60.000	-564.007	0.0	51.9	not
B005-S	14	657.022	60.000	-563.991	0.0	34.5	not
F001-H	14	655.893	60.000	-564.243	0.0	30.0	not
F001-S	14	667.596	60.000	-564.029	0.0	40.5	not
F002-H	14	547.675	60.000	-564.303	0.0	73.5	CATCH
F002-S	14	539.520	60.000	-564.096	0.0	60.0	CATCH
F003-H	14	648.854	60.000	-564.191	0.0	51.3	not
F003-S	14	650.393	60.000	-564.440	0.0	61.5	not
F004-H	14	559.817	60.000	-563.936	0.0	99.3	CATCH

F004-S	14	558.274	60.000	-563.859	0.0	93.0	CATCH
F005-H	14	544.133	60.000	-563.817	0.0	88.8	CATCH
F005-S	14	544.657	60.000	-562.840	0.0	122.1	CATCH
F006-H	14	654.604	60.000	-563.864	0.0	93.6	not
F006-S	14	658.226	60.000	-564.413	0.0	62.1	not
F007-H	14	656.817	60.000	-563.862	90.0	48.9	not
F007-S	14	653.642	60.000	-564.405	93.0	57.9	not
F008-H	14	646.408	60.000	-564.180	0.0	34.8	not
F008-S	14	651.063	60.000	-564.111	0.0	36.6	not
F009-H	14	657.402	60.000	-563.522	54.0	70.8	not
F009-S	14	653.913	94.000	-562.601	0.0	149.4	not
F010-H	14	541.628	60.000	-564.284	0.0	47.1	CATCH
F010-S	14	653.838	60.000	-563.826	0.0	50.4	not
F011-H	14	653.098	60.000	-564.017	0.0	38.1	not
F011-S	14	654.622	60.000	-564.110	0.0	52.8	not
F012-H	14	650.411	60.000	-563.751	0.0	88.8	not
F012-S	14	653.307	60.000	-564.284	0.0	94.2	not
F013-H	14	660.289	60.000	-564.092	0.0	101.1	not
F013-S	14	665.732	60.000	-562.140	0.0	150.0	not
F014-H	14	650.141	60.000	-564.421	0.0	60.0	not
F014-S	14	657.645	60.000	-564.411	0.0	79.2	not
F015-H	14	658.256	60.000	-563.874	0.0	75.6	not
F015-S	14	659.339	60.000	-563.267	0.0	107.7	not
F016-H	14	648.887	60.000	-564.267	90.0	33.3	not
F016-S	14	654.483	60.000	-564.114	90.0	27.9	not
F017-H	14	654.311	60.000	-564.179	0.0	49.5	not
F017-S	14	656.146	60.000	-563.809	0.0	58.5	not
F018-H	14	648.465	60.000	-564.307	63.0	48.6	not
F018-S	14	652.986	60.000	-563.712	0.0	56.4	not
F019-H	14	545.689	60.000	-563.468	39.0	72.0	CATCH
F019-S	14	661.761	60.000	-563.838	0.0	66.0	not
F020-H	14	643.653	60.000	-564.207	0.0	63.3	not
F020-S	14	649.638	60.000	-563.910	0.0	74.1	not
F021-H	14	658.103	60.000	-563.979	0.0	52.5	not
F021-S	14	656.507	60.000	-563.734	0.0	117.3	not
F022-H	14	650.892	60.000	-564.345	0.0	81.6	not
F022-S	14	653.492	60.000	-564.082	0.0	69.9	not
F023-H	14	654.380	60.000	-564.351	0.0	51.6	not
F023-S	14	660.551	60.000	-563.267	0.0	96.9	not
F024-H	14	662.973	60.000	-564.200	90.0	41.7	not
F024-S	14	658.245	60.000	-564.095	0.0	27.3	not
F025-H	14	659.999	60.000	-563.762	0.0	68.4	not
F025-S	14	666.996	60.000	-564.300	0.0	80.4	not
F026-H	14	655.524	60.000	-563.479	0.0	89.4	not
F026-S	14	656.884	60.000	-563.140	0.0	83.1	not
F027-H	14	656.093	60.000	-563.884	0.0	74.4	not
F027-S	14	653.867	60.000	-562.928	0.0	99.6	not
F028-H	14	648.351	60.000	-564.260	0.0	111.3	not
F028-S	14	664.922	60.000	-563.447	0.0	92.1	not
F029-H	14	649.515	60.000	-563.796	0.0	57.3	not
F029-S	14	653.513	60.000	-564.021	0.0	42.6	not
F030-H	14	651.425	60.000	-563.820	0.0	62.1	not
F030-S	14	661.321	60.000	-563.854	0.0	80.4	not
F031-H	14	649.990	60.000	-564.350	0.0	36.3	not
F031-S	14	656.936	60.000	-564.288	0.0	54.9	not
F032-H	14	649.804	60.000	-564.406	0.0	82.8	not
F032-S	14	652.745	60.000	-564.024	0.0	82.5	not
F033-H	14	655.805	60.000	-563.923	0.0	45.6	not
F033-S	14	655.207	60.000	-563.812	0.0	107.1	not
F034-H	14	652.197	60.000	-562.793	0.0	120.3	not

File	Room	X	Y	Z	Rotate	Speed	RESULT
F034-S	14	657.855	60.000	-563.727	0.0	125.7	not
F035-H	14	660.618	60.000	-564.141	90.0	49.8	not
F035-S	14	657.761	60.000	-564.061	0.0	52.2	not
F036-H	14	652.706	60.000	-564.436	0.0	39.9	not
F036-S	14	654.939	60.000	-564.157	0.0	29.4	not
F037-H	14	662.130	60.000	-563.774	0.0	58.5	not
F037-S	14	662.682	60.000	-564.320	0.0	117.6	not
F038-H	14	658.665	60.000	-564.022	0.0	56.7	not
F038-S	14	667.359	60.000	-564.470	0.0	72.3	not
F040-H	14	647.781	60.000	-563.808	0.0	51.9	not
F040-S	14	656.453	60.000	-564.261	0.0	47.1	not
F041-H	14	542.276	60.000	-564.477	0.0	33.6	CATCH
F041-S	14	545.255	60.000	-564.431	0.0	53.7	CATCH
F042-H	14	646.487	60.000	-563.906	0.0	42.0	not
F042-S	14	651.778	60.000	-563.951	0.0	67.5	not
F043-H	14	652.694	60.000	-563.983	0.0	42.6	not
F043-S	14	654.118	60.000	-564.480	0.0	69.6	not
H001-H	14	661.177	60.000	-563.581	0.0	60.3	not
H002-H	14	657.881	60.000	-564.392	0.0	53.4	not
H003-H	14	654.244	60.000	-563.484	0.0	85.8	not
I001-H	14	655.009	60.000	-564.458	0.0	84.9	not
I001-S	14	656.749	60.000	-564.455	0.0	91.8	not
P001-H	14	646.135	60.000	-564.174	90.0	68.7	not
P001-S	14	654.043	60.000	-563.545	0.0	64.5	not
P002-H	14	655.437	60.000	-564.084	0.0	53.4	not
P002-S	14	664.957	60.000	-564.034	0.0	71.4	not
P003-H	14	657.944	60.000	-564.251	0.0	25.5	not
P003-S	14	668.880	60.000	-564.293	0.0	29.1	not
P004-H	14	661.895	60.000	-564.009	0.0	57.0	not
P004-S	14	663.948	60.000	-564.325	0.0	59.7	not
P005-H	14	651.025	60.000	-564.063	90.0	30.3	not
P005-S	14	653.394	60.000	-564.004	90.0	32.7	not
P006-H	14	655.894	60.000	-563.481	0.0	83.7	not
P006-S	14	661.311	60.000	-563.959	0.0	48.0	not
P007-H	14	650.244	60.000	-564.257	0.0	23.1	not
P007-S	14	661.283	60.000	-563.770	0.0	49.8	not
P008-H	14	656.638	60.000	-564.375	0.0	70.2	not
P008-S	14	668.530	60.000	-564.249	0.0	136.2	not
P009-H	14	646.292	60.000	-564.147	0.0	85.2	not
P009-S	14	647.071	60.000	-564.042	0.0	145.8	not
P010-H	14	663.966	60.000	-563.673	0.0	81.3	not
P010-S	14	664.589	60.000	-563.874	0.0	55.2	not

Task Room 15 Reduced Data

File	Room	X	Y	Z	Rotate	Speed	RESULT
A001-H	15	1055.023	125.000	-719.432	0.0	46.2	FLY
A002-H	15	1054.582	60.000	-617.742	0.0	76.5	no
A003-H	15	1055.234	60.000	-616.508	0.0	36.6	no
A004-H	15	1054.928	125.000	-719.589	0.0	81.0	FLY
A005-H	15	1055.074	125.000	-703.650	0.0	48.9	FLY
B001-H	15	1055.586	60.000	-717.300	0.0	15.9	no
B001-S	15	1055.640	60.000	-617.025	0.0	18.6	no
B002-H	15	1055.544	60.000	-616.396	0.0	61.2	no
B002-S	15	1055.185	125.000	-713.514	0.0	62.1	FLY
B003-H	15	1055.307	60.000	-714.455	90.0	51.9	m/b
B003-S	15	1055.180	121.000	-714.348	0.0	66.9	FLY
B004-H	15	1055.236	60.000	-624.874	0.0	57.0	no
B004-S	15	1054.489	125.000	-714.642	0.0	83.7	FLY
B005-H	15	1055.573	60.000	-634.666	0.0	24.9	no

B005-S	15	1055.497	60.000	-629.263	0.0	23.7	no
F001-H	15	1055.523	119.000	-709.297	0.0	21.6	FLY
F001-S	15	1055.191	125.000	-719.699	0.0	49.2	FLY
F002-H	15	1054.824	60.000	-625.009	0.0	88.5	no
F002-S	15	1054.880	125.000	-708.678	0.0	59.1	FLY
F003-H	15	1054.870	125.000	-705.937	0.0	78.9	FLY
F003-S	15	1055.310	125.000	-709.341	0.0	94.5	FLY
F004-H	15	1054.753	60.000	-618.161	0.0	109.5	no
F004-S	15	1055.129	88.000	-718.105	0.0	86.1	FLY
F005-H	15	1054.934	125.000	-701.056	0.0	113.4	FLY
F005-S	15	1055.067	119.000	-702.714	0.0	132.3	FLY
F006-H	15	1054.513	123.000	-711.656	0.0	103.2	FLY
F006-S	15	1055.225	125.000	-715.583	0.0	81.0	FLY
F007-H	15	1054.926	125.000	-709.742	0.0	60.9	FLY
F007-S	15	1055.442	125.000	-708.236	0.0	59.1	FLY
F008-H	15	1055.400	125.000	-712.300	0.0	44.4	FLY
F008-S	15	1055.074	125.000	-711.343	0.0	44.4	FLY
F009-H	15	1054.938	60.000	-621.012	90.0	75.6	m/b
F009-S	15	1055.084	108.000	-713.506	0.0	145.8	FLY
F010-H	15	1055.610	125.000	-719.096	0.0	55.5	FLY
F010-S	15	1054.940	125.000	-723.580	0.0	60.6	FLY
F011-H	15	1055.643	60.000	-625.178	0.0	24.0	no
F011-S	15	1055.669	125.000	-710.241	0.0	51.6	FLY
F012-H	15	1054.783	125.000	-703.176	0.0	90.9	FLY
F012-S	15	1054.841	125.000	-701.205	0.0	97.2	FLY
F013-H	15	1055.646	125.000	-714.302	0.0	95.7	FLY
F013-S	15	1053.825	60.000	-626.180	0.0	146.7	no
F014-H	15	1055.415	60.000	-617.367	0.0	63.0	no
F014-S	15	1055.667	125.000	-710.484	0.0	82.8	FLY
F015-H	15	1055.449	125.000	-709.302	0.0	73.2	FLY
F015-S	15	1054.840	125.000	-708.683	0.0	124.8	FLY
F016-H	15	1055.308	125.000	-712.225	0.0	33.0	FLY
F016-S	15	1055.614	60.000	-619.542	90.0	19.5	m/b
F017-H	15	1055.273	125.000	-702.579	0.0	42.3	FLY
F017-S	15	1055.270	125.000	-715.413	0.0	53.7	FLY
F018-H	15	1055.314	125.000	-707.044	0.0	51.0	FLY
F018-S	15	1055.530	125.000	-708.367	0.0	59.4	FLY
F019-H	15	1054.742	101.000	-714.144	0.0	73.2	FLY
F019-S	15	1055.419	125.000	-718.447	0.0	78.6	FLY
F020-H	15	1055.154	125.000	-708.721	0.0	62.1	FLY
F020-S	15	1055.749	60.000	-618.158	0.0	67.5	no
F021-H	15	1055.232	60.000	-616.024	0.0	67.2	no
F021-S	15	1054.918	125.000	-708.501	0.0	103.8	FLY
F022-H	15	1055.717	60.000	-618.607	0.0	91.8	no
F022-S	15	1055.408	60.000	-621.945	0.0	94.5	no
F023-H	15	1055.436	125.000	-705.489	0.0	51.9	FLY
F023-S	15	1055.484	125.000	-715.622	0.0	96.3	FLY
F024-H	15	1055.145	125.000	-710.240	0.0	48.0	FLY
F024-S	15	1055.205	125.000	-711.571	0.0	43.5	FLY
F025-H	15	1055.620	125.000	-712.367	0.0	54.6	FLY
F025-S	15	1055.033	125.000	-720.402	0.0	60.6	FLY
F026-H	15	1055.707	60.000	-621.357	0.0	83.7	no
F026-S	15	1054.902	125.000	-716.411	0.0	80.4	FLY
F027-H	15	1055.725	125.000	-703.516	0.0	51.0	FLY
F027-S	15	1055.183	125.000	-702.128	0.0	112.8	FLY
F028-H	15	1055.665	60.000	-620.608	0.0	87.0	no
F028-S	15	1055.444	60.000	-621.434	0.0	68.4	no
F029-H	15	1054.896	60.000	-615.877	0.0	60.9	no
F029-S	15	1055.037	125.000	-713.544	0.0	64.8	FLY
F030-H	15	1055.219	125.000	-702.626	0.0	46.2	FLY

179

File	Room	X	Y	Z	Rotate	Speed	RESULT
F030-S	15	1054.728	125.000	-702.597	0.0	69.0	FLY
F031-H	15	1055.081	60.000	-619.929	0.0	42.3	no
F031-S	15	1054.490	60.000	-614.488	0.0	80.7	no
F032-H	15	1054.713	125.000	-713.565	0.0	90.0	FLY
F032-S	15	1055.513	60.000	-628.875	0.0	85.2	no
F033-H	15	1053.761	116.000	-724.922	0.0	120.0	FLY
F033-S	15	1054.088	100.000	-723.589	0.0	126.6	FLY
F034-H	15	1054.556	125.000	-706.938	0.0	123.9	FLY
F034-S	15	1055.372	60.000	-617.730	0.0	122.7	no
F035-H	15	1055.316	60.000	-620.072	90.0	34.8	m/b
F035-S	15	1055.662	81.000	-713.897	0.0	24.6	FLY
F036-H	15	1055.617	125.000	-715.801	0.0	30.6	FLY
F036-S	15	1055.292	125.000	-717.283	0.0	29.1	FLY
F037-H	15	1054.719	119.000	-713.498	0.0	75.6	FLY
F037-S	15	1054.860	125.000	-714.017	0.0	74.7	FLY
F038-H	15	1055.118	60.000	-711.897	0.0	60.9	no
F038-S	15	1054.954	60.000	-719.605	0.0	78.0	no
F040-H	15	1055.605	60.000	-624.281	0.0	50.4	no
F040-S	15	1055.369	125.000	-708.650	0.0	51.9	FLY
F041-H	15	1055.729	60.000	-625.032	0.0	16.5	no
F041-S	15	1055.440	60.000	-714.250	0.0	53.7	no
F042-H	15	1055.551	60.000	-622.129	0.0	41.4	no
F042-S	15	1055.458	60.000	-623.332	0.0	55.8	no
F043-H	15	1055.196	125.000	-708.863	0.0	50.1	FLY
F043-S	15	1054.696	125.000	-708.663	0.0	69.3	FLY
H001-H	15	1054.993	60.000	-624.252	0.0	62.4	no
H002-H	15	1055.476	60.000	-623.697	0.0	34.8	no
H003-H	15	1055.037	60.000	-621.142	0.0	66.9	no
I001-H	15	1055.012	95.000	-714.294	0.0	62.4	FLY
I001-S	15	1055.531	74.000	-723.837	0.0	85.2	FLY
P001-H	15	1054.555	60.000	-622.658	36.0	79.2	m/b
P001-S	15	1055.297	160.000	-708.000	0.0	77.4	FLY
P002-H	15	1054.931	60.000	-623.222	0.0	60.3	no
P002-S	15	1054.832	60.000	-714.763	90.0	87.6	m/b
P003-H	15	1055.517	60.000	-622.760	0.0	16.8	no
P003-S	15	1055.562	60.000	-605.712	0.0	23.4	no
P004-H	15	1055.442	60.000	-635.756	90.0	49.2	m/b
P004-S	15	1055.525	60.000	-618.383	0.0	32.7	no
P005-H	15	1055.496	210.000	-707.825	0.0	18.9	FLY
P005-S	15	1055.041	112.000	-713.392	0.0	42.9	FLY
P006-H	15	1055.664	164.000	-699.736	0.0	72.6	FLY
P006-S	15	1055.506	60.000	-615.844	0.0	65.4	no
P007-H	15	1055.484	60.000	-623.882	90.0	21.6	m/b
P007-S	15	1055.315	252.000	-710.261	0.0	35.7	FLY
P008-H	15	1054.864	60.000	-630.921	0.0	68.4	no
P008-S	15	1054.879	236.000	-702.533	0.0	65.4	FLY
P009-H	15	1055.307	156.000	-704.920	0.0	85.8	FLY
P009-S	15	1054.525	124.000	-710.049	0.0	146.7	FLY
P010-H	15	1055.690	60.000	-625.746	0.0	72.6	no
P010-S	15	1055.310	60.000	-625.029	0.0	61.5	no

Task Room 16 Reduced Data

File	Room	X	Y	Z	Rotate	Speed	RESULT
A001-H	16	1194.963	60.000	-222.495	72.0	70.2	ROTATE
A002-H	16	1192.719	60.000	-222.417	84.0	70.8	ROTATE
A003-H	16	1192.842	60.000	-222.122	90.0	58.8	ROTATE
A004-H	16	1197.894	60.000	-222.089	0.0	144.9	no
A005-H	16	1194.634	60.000	-221.617	90.0	82.2	ROTATE
B001-H	16	1200.035	60.000	-221.571	0.0	11.7	no

B001-S	16	1192.351	60.000	-221.586	0.0	20.7	no
B002-H	16	1200.767	60.000	-222.072	0.0	63.6	no
B002-S	16	1193.532	60.000	-222.721	90.0	91.5	ROTATE
B003-H	16	1201.819	60.000	-222.084	0.0	58.5	no
B003-S	16	1192.583	60.000	-222.066	0.0	72.9	no
B004-H	16	1196.085	60.000	-221.880	0.0	40.5	no
B004-S	16	1195.158	60.000	-222.251	90.0	74.4	ROTATE
B005-H	16	1207.162	60.000	-221.716	0.0	31.5	no
B005-S	16	1194.427	60.000	-222.091	0.0	45.9	no
F001-H	16	1192.687	60.000	-221.645	90.0	27.9	ROTATE
F001-S	16	1192.041	60.000	-222.391	90.0	58.8	ROTATE
F002-H	16	1192.385	60.000	-222.140	90.0	89.1	ROTATE
F002-S	16	1188.959	60.000	-221.866	90.0	82.2	ROTATE
F003-H	16	1198.751	60.000	-222.452	90.0	78.3	ROTATE
F003-S	16	1196.918	60.000	-221.510	90.0	103.5	ROTATE
F004-H	16	1188.780	60.000	-222.445	0.0	123.9	no
F004-S	16	1194.593	60.000	-222.389	0.0	82.2	no
F005-H	16	1193.845	60.000	-221.717	90.0	79.8	ROTATE
F005-S	16	1197.243	60.000	-221.852	33.0	123.6	ROTATE
F006-H	16	1198.725	60.000	-222.589	90.0	119.1	ROTATE
F006-S	16	1193.055	60.000	-222.554	90.0	84.3	ROTATE
F007-H	16	1195.560	60.000	-221.605	90.0	75.0	ROTATE
F007-S	16	1194.526	60.000	-221.508	90.0	74.4	ROTATE
F008-H	16	1196.412	60.000	-221.718	15.0	41.1	no
F008-S	16	1195.291	60.000	-221.589	90.0	29.1	ROTATE
F009-H	16	1189.601	60.000	-222.201	90.0	43.8	ROTATE
F009-S	16	1193.380	60.000	-222.227	60.0	150.0	ROTATE
F010-H	16	1195.504	60.000	-222.040	90.0	67.5	ROTATE
F010-S	16	1192.569	60.000	-221.730	90.0	74.1	ROTATE
F011-H	16	1191.089	60.000	-221.881	90.0	37.2	ROTATE
F011-S	16	1193.959	60.000	-221.730	90.0	54.6	ROTATE
F012-H	16	1191.594	60.000	-221.819	0.0	74.1	no
F012-S	16	1189.527	60.000	-221.732	0.0	93.0	no
F013-H	16	1197.628	60.000	-222.952	90.0	90.9	ROTATE
F013-S	16	1194.748	60.000	-221.948	0.0	130.2	no
F014-H	16	1192.150	60.000	-221.823	0.0	62.7	no
F014-S	16	1196.195	60.000	-221.942	93.0	80.4	ROTATE
F015-H	16	1192.701	60.000	-222.458	90.0	72.9	ROTATE
F015-S	16	1193.094	60.000	-222.336	90.0	108.6	ROTATE
F016-H	16	1193.245	60.000	-221.747	90.0	33.9	ROTATE
F016-S	16	1194.211	60.000	-221.676	90.0	19.2	ROTATE
F017-H	16	1195.072	60.000	-221.635	90.0	52.2	ROTATE
F017-S	16	1194.964	60.000	-222.004	63.0	65.1	ROTATE
F018-H	16	1194.673	60.000	-221.934	90.0	48.3	ROTATE
F018-S	16	1196.683	60.000	-221.787	90.0	54.0	ROTATE
F019-H	16	1192.809	60.000	-222.221	90.0	59.1	ROTATE
F019-S	16	1192.977	60.000	-221.638	90.0	107.1	ROTATE
F020-H	16	1192.220	60.000	-221.852	90.0	81.3	ROTATE
F020-S	16	1193.046	60.000	-222.407	90.0	70.5	ROTATE
F021-H	16	1190.536	60.000	-222.484	90.0	88.5	ROTATE
F021-S	16	1190.891	60.000	-222.703	66.0	118.5	ROTATE
F022-H	16	1200.134	60.000	-222.982	90.0	107.7	ROTATE
F022-S	16	1198.055	60.000	-222.388	36.0	97.2	ROTATE
F023-H	16	1192.149	60.000	-221.891	0.0	50.1	no
F023-S	16	1192.665	60.000	-222.954	87.0	87.6	ROTATE
F024-H	16	1195.946	60.000	-221.813	90.0	47.7	ROTATE
F024-S	16	1194.443	60.000	-221.835	90.0	56.4	ROTATE
F025-H	16	1196.223	60.000	-221.933	90.0	65.4	ROTATE
F025-S	16	1195.668	60.000	-221.835	78.0	64.2	ROTATE
F026-H	16	1194.393	60.000	-223.041	87.0	91.8	ROTATE

F026-S	16	1194.543	60.000	-222.792	90.0	83.7	ROTATE
F027-H	16	1192.735	60.000	-222.262	90.0	55.5	ROTATE
F027-S	16	1192.055	60.000	-222.549	0.0	116.7	no
F028-H	16	1194.961	60.000	-221.998	90.0	84.0	ROTATE
F028-S	16	1194.240	60.000	-221.615	84.0	62.7	ROTATE
F029-H	16	1196.326	60.000	-222.601	90.0	68.7	ROTATE
F029-S	16	1195.556	60.000	-221.796	90.0	54.0	ROTATE
F030-H	16	1193.785	60.000	-222.422	90.0	56.1	ROTATE
F030-S	16	1193.890	60.000	-221.877	90.0	63.3	ROTATE
F031-H	16	1193.546	60.000	-222.059	18.0	43.2	ROTATE
F031-S	16	1192.939	60.000	-222.688	75.0	80.1	ROTATE
F032-H	16	1194.985	60.000	-223.156	45.0	109.8	ROTATE
F032-S	16	1190.864	60.000	-222.344	90.0	90.9	ROTATE
F033-H	16	1198.287	60.000	-222.543	90.0	145.2	ROTATE
F033-S	16	1197.277	60.000	-222.274	0.0	147.3	no
F034-H	16	1192.416	60.000	-222.760	90.0	127.2	ROTATE
F034-S	16	1195.430	60.000	-222.853	90.0	124.8	ROTATE
F035-H	16	1192.517	60.000	-221.526	90.0	37.2	ROTATE
F035-S	16	1193.103	60.000	-221.691	90.0	43.2	ROTATE
F036-H	16	1195.850	60.000	-221.976	0.0	42.6	no
F036-S	16	1198.958	60.000	-222.220	90.0	45.6	ROTATE
F037-H	16	1196.935	60.000	-222.123	90.0	71.1	ROTATE
F037-S	16	1193.258	60.000	-222.806	75.0	111.9	ROTATE
F038-H	16	1198.201	60.000	-222.675	90.0	69.6	ROTATE
F038-S	16	1204.368	60.000	-221.566	90.0	64.2	ROTATE
F040-H	16	1192.665	60.000	-222.076	0.0	59.1	no
F040-S	16	1195.967	60.000	-222.227	0.0	49.5	no
F041-H	16	1190.292	60.000	-221.519	0.0	20.7	no
F041-S	16	1191.061	60.000	-221.616	90.0	43.2	ROTATE
F042-H	16	1194.796	60.000	-222.186	90.0	41.4	ROTATE
F042-S	16	1194.752	60.000	-222.003	0.0	55.8	no
F043-H	16	1193.021	60.000	-221.868	0.0	46.8	no
F043-S	16	1193.885	60.000	-221.847	0.0	53.1	no
H001-H	16	1193.920	60.000	-222.186	90.0	42.3	ROTATE
H002-H	16	1193.042	60.000	-221.807	0.0	42.3	no
H003-H	16	1259.446	60.000	-221.557	0.0	80.4	no
I001-H	16	1191.226	60.000	-222.549	90.0	89.1	ROTATE
I001-S	16	1195.286	60.000	-221.685	90.0	85.5	ROTATE
P001-H	16	1195.000	60.000	-222.584	90.0	78.9	ROTATE
P001-S	16	1195.944	60.000	-221.593	90.0	65.4	ROTATE
P002-H	16	1194.076	60.000	-222.607	90.0	69.6	ROTATE
P002-S	16	1197.198	60.000	-222.269	90.0	62.4	ROTATE
P003-H	16	1194.345	60.000	-221.654	90.0	18.9	ROTATE
P003-S	16	1197.878	60.000	-221.688	90.0	43.5	ROTATE
P004-H	16	1192.167	60.000	-221.830	90.0	54.9	ROTATE
P004-S	16	1193.429	60.000	-221.672	63.0	26.4	ROTATE
P005-H	16	1194.516	60.000	-221.925	90.0	44.1	ROTATE
P005-S	16	1193.548	60.000	-222.333	90.0	57.3	ROTATE
P006-H	16	1191.039	60.000	-221.776	0.0	25.8	no
P006-S	16	1194.755	60.000	-222.141	0.0	46.8	no
P007-H	16	1194.039	60.000	-221.534	90.0	49.8	ROTATE
P007-S	16	1193.847	60.000	-221.589	90.0	31.8	ROTATE
P008-H	16	1198.181	60.000	-222.320	0.0	58.8	no
P008-S	16	1194.539	60.000	-222.422	0.0	67.8	no
P009-H	16	1193.603	60.000	-222.274	0.0	99.3	no
P009-S	16	1185.590	60.000	-223.444	0.0	150.0	no
P010-H	16	1196.419	60.000	-222.183	0.0	83.1	no
P010-S	16	1198.429	60.000	-221.838	0.0	60.3	no

Task Room 17 Reduced Data

File	Room	X	Y	Z	Rotate	Speed	RESULT
A001-H	17	1644.680	60.000	-147.935	0.0	67.8	CATCH
A002-H	17	1644.861	60.000	-144.577	0.0	66.0	CATCH
A003-H	17	1644.765	60.000	-151.049	0.0	41.4	CATCH
A004-H	17	1644.117	60.000	-145.962	0.0	79.5	CATCH
A005-H	17	1645.155	60.000	-142.910	0.0	34.2	CATCH
B001-H	17	1645.109	60.000	-145.229	0.0	10.2	CATCH
B001-S	17	1644.982	60.000	-30.987	0.0	16.5	not
B002-H	17	1645.052	60.000	-145.934	0.0	46.5	CATCH
B002-S	17	1645.151	60.000	-16.838	0.0	66.3	not
B003-H	17	1644.482	60.000	-150.553	0.0	57.6	CATCH
B003-S	17	1645.041	60.000	-23.170	0.0	70.5	not
B004-H	17	1644.425	60.000	-148.411	0.0	55.5	CATCH
B004-S	17	1645.003	60.000	-29.192	0.0	87.9	not
B005-H	17	1645.086	60.000	-153.279	0.0	31.5	CATCH
B005-S	17	1644.952	60.000	-33.289	0.0	38.7	not
F001-H	17	1644.602	60.000	-30.433	0.0	46.8	not
F001-S	17	1644.932	60.000	-15.166	0.0	49.8	not
F002-H	17	1644.536	60.000	-150.095	0.0	89.1	CATCH
F002-S	17	1645.100	60.000	-41.602	0.0	62.7	not
F003-H	17	1644.109	60.000	-146.346	0.0	70.2	CATCH
F003-S	17	1644.807	60.000	-135.098	0.0	84.9	CATCH
F004-H	17	1644.038	60.000	-144.606	0.0	89.7	CATCH
F004-S	17	1645.182	60.000	-154.464	0.0	69.0	CATCH
F005-H	17	1645.156	60.000	-42.056	0.0	66.6	not
F005-S	17	1643.671	60.000	-137.462	0.0	120.9	CATCH
F006-H	17	1644.182	60.000	-141.669	0.0	127.8	CATCH
F006-S	17	1644.646	60.000	-144.378	0.0	77.4	CATCH
F007-H	17	1644.912	60.000	-31.591	90.0	52.5	not
F007-S	17	1644.822	60.000	-28.943	0.0	63.3	not
F008-H	17	1645.156	60.000	-27.181	0.0	43.8	not
F008-S	17	1645.168	60.000	-27.123	0.0	52.2	not
F009-H	17	1645.229	60.000	-40.449	75.0	95.7	not
F009-S	17	1644.945	60.000	-28.459	30.0	149.1	not
F010-H	17	1645.203	60.000	-35.032	0.0	67.8	not
F010-S	17	1644.143	60.000	-38.201	0.0	80.1	not
F011-H	17	1644.783	60.000	-41.402	0.0	43.2	not
F011-S	17	1645.151	60.000	-34.521	0.0	50.4	not
F012-H	17	1644.980	60.000	-32.235	0.0	83.4	not
F012-S	17	1644.061	60.000	-31.110	0.0	92.7	not
F013-H	17	1644.501	60.000	-37.652	0.0	90.6	not
F013-S	17	1644.181	60.000	-26.681	0.0	133.2	not
F014-H	17	1644.385	60.000	-36.103	0.0	74.1	not
F014-S	17	1644.972	60.000	-33.096	0.0	51.6	not
F015-H	17	1644.457	60.000	-28.244	0.0	75.6	not
F015-S	17	1644.973	60.000	-27.284	0.0	86.4	not
F016-H	17	1645.119	60.000	-27.820	90.0	33.6	not
F016-S	17	1645.200	60.000	-35.072	90.0	22.2	not
F017-H	17	1644.756	60.000	-53.924	57.0	42.6	not
F017-S	17	1644.892	60.000	-39.303	0.0	59.7	not
F018-H	17	1644.747	60.000	-36.331	36.0	35.1	not
F018-S	17	1644.504	60.000	-39.307	0.0	54.0	not
F019-H	17	1644.635	60.000	-38.762	0.0	57.3	not
F019-S	17	1643.869	60.000	-30.065	0.0	109.5	not
F020-H	17	1644.632	60.000	-33.118	0.0	78.3	not
F020-S	17	1644.864	60.000	-28.612	0.0	71.1	not
F021-H	17	1645.080	60.000	-31.387	0.0	84.3	not
F021-S	17	1643.927	60.000	-26.968	0.0	93.6	not

F022-H	17	1644.402	60.000	-143.031	0.0	83.7	CATCH
F022-S	17	1644.260	60.000	-38.501	0.0	69.0	not
F023-H	17	1645.047	60.000	-34.171	0.0	41.1	not
F023-S	17	1644.705	60.000	-33.632	0.0	87.9	not
F024-H	17	1645.223	60.000	-28.743	0.0	43.2	not
F024-S	17	1644.728	60.000	-23.512	0.0	38.7	not
F025-H	17	1644.336	60.000	-26.487	0.0	78.9	not
F025-S	17	1644.959	60.000	-21.404	0.0	70.2	not
F026-H	17	1644.551	60.000	-30.866	0.0	82.8	not
F026-S	17	1644.268	60.000	-27.303	0.0	70.8	not
F027-H	17	1644.104	60.000	-29.437	0.0	80.1	not
F027-S	17	1643.782	60.000	-28.895	0.0	101.1	not
F028-H	17	1644.905	60.000	-40.256	0.0	22.8	not
F028-S	17	1645.010	60.000	-36.351	0.0	84.0	not
F029-H	17	1644.290	60.000	-141.763	0.0	72.6	CATCH
F029-S	17	1645.028	60.000	-25.171	0.0	40.8	not
F030-H	17	1644.148	60.000	-30.975	0.0	72.3	not
F030-S	17	1644.655	60.000	-37.117	0.0	75.6	not
F031-H	17	1645.109	60.000	-34.291	0.0	51.6	not
F031-S	17	1644.849	60.000	-30.866	0.0	40.5	not
F032-H	17	1645.195	60.000	-39.424	0.0	111.0	not
F032-S	17	1644.097	60.000	-35.997	0.0	94.5	not
F033-H	17	1645.070	60.000	-26.591	0.0	86.7	not
F033-S	17	1644.437	60.000	-33.917	0.0	119.7	not
F034-H	17	1644.598	60.000	-30.546	0.0	124.5	not
F034-S	17	1643.704	60.000	-29.443	0.0	117.9	not
F035-H	17	1645.067	60.000	-25.067	90.0	55.5	not
F035-S	17	1645.076	60.000	-29.402	0.0	43.2	not
F036-H	17	1644.853	60.000	-18.737	0.0	33.3	not
F036-S	17	1645.176	60.000	-37.686	0.0	22.2	not
F037-H	17	1644.833	60.000	-40.599	0.0	53.1	not
F037-S	17	1643.955	60.000	-27.250	0.0	94.5	not
F038-H	17	1644.583	60.000	-41.616	0.0	64.5	not
F038-S	17	1644.956	60.000	-30.840	0.0	69.3	not
F040-H	17	1645.181	60.000	-38.618	0.0	51.6	not
F040-S	17	1644.989	60.000	-26.601	0.0	51.0	not
F041-H	17	1645.147	60.000	-142.363	0.0	16.8	CATCH
F041-S	17	1644.841	60.000	-143.998	0.0	49.8	CATCH
F042-H	17	1644.718	60.000	-30.812	0.0	46.2	not
F042-S	17	1644.474	60.000	-28.622	0.0	51.3	not
F043-H	17	1644.990	60.000	-25.327	0.0	20.7	not
F043-S	17	1644.655	60.000	-31.105	0.0	50.1	not
H001-H	17	1644.852	60.000	-27.992	0.0	77.7	not
H002-H	17	1645.152	60.000	-48.646	0.0	34.5	not
H003-H	17	1644.983	60.000	-38.535	0.0	71.1	not
I001-H	17	1644.955	60.000	-37.540	0.0	91.8	not
I001-S	17	1644.413	60.000	-30.541	0.0	88.8	not
P001-H	17	1644.236	60.000	-31.278	0.0	67.8	not
P001-S	17	1645.219	60.000	-28.271	0.0	68.7	not
P002-H	17	1644.230	60.000	-32.319	0.0	67.2	not
P002-S	17	1644.620	60.000	-39.294	0.0	68.4	not
P003-H	17	1645.198	60.000	-43.123	0.0	15.0	not
P003-S	17	1645.107	60.000	-15.385	0.0	33.6	not
P004-H	17	1644.820	60.000	-31.329	0.0	61.2	not
P004-S	17	1644.679	60.000	-18.714	0.0	44.1	not
P005-H	17	1645.068	60.000	-34.284	90.0	13.2	not
P005-S	17	1645.249	60.000	-30.162	90.0	31.8	not
P006-H	17	1644.383	60.000	-15.179	0.0	87.9	not
P006-S	17	1645.016	60.000	-15.155	0.0	60.9	not
P007-H	17	1644.853	60.000	-46.890	90.0	28.8	not

File	Room	X	Y	Z	Rotate	Speed	RESULT
P007-S	17	1644.773	60.000	-23.589	0.0	33.6	not
P008-H	17	1644.970	60.000	-39.291	0.0	58.2	not
P008-S	17	1644.923	60.000	-34.238	0.0	91.8	not
P009-H	17	1644.029	60.000	-40.044	0.0	132.6	not
P009-S	17	1642.896	60.000	-30.595	0.0	139.5	not
P010-H	17	1644.016	60.000	-128.275	0.0	85.8	CATCH
P010-S	17	1645.200	60.000	-48.669	0.0	54.0	not

Task Room 18 Reduced Data

File	Room	X	Y	Z	Rotate	Speed	RESULT
A001-H	18	1811.478	60.000	-564.204	90.0	61.8	m/b
A002-H	18	1719.157	60.000	-563.307	0.0	87.9	no
A003-H	18	1816.408	125.000	-564.118	0.0	54.6	FLY
A004-H	18	1810.821	121.000	-564.179	0.0	91.5	FLY
A005-H	18	1812.511	125.000	-564.214	0.0	53.7	FLY
B001-H	18	1821.798	60.000	-564.415	0.0	12.0	no
B001-S	18	1712.299	60.000	-564.405	0.0	29.4	no
B002-H	18	1814.921	125.000	-564.177	0.0	59.4	FLY
B002-S	18	1722.511	60.000	-564.336	33.0	70.5	m/b
B003-H	18	1803.665	88.000	-563.692	0.0	52.8	FLY
B003-S	18	1715.907	60.000	-563.579	0.0	60.6	no
B004-H	18	1711.565	60.000	-564.193	0.0	61.8	no
B004-S	18	1719.813	60.000	-564.450	0.0	87.0	no
B005-H	18	1719.392	60.000	-564.021	0.0	33.3	no
B005-S	18	1727.699	60.000	-564.114	0.0	42.3	no
F001-H	18	1819.542	111.000	-564.421	0.0	39.3	FLY
F001-S	18	1848.031	125.000	-563.912	0.0	43.2	FLY
F002-H	18	1794.222	125.000	-564.349	0.0	88.2	FLY
F002-S	18	1803.269	99.000	-564.150	0.0	62.1	FLY
F003-H	18	1801.067	125.000	-563.374	0.0	90.0	FLY
F003-S	18	1804.303	125.000	-563.269	0.0	95.1	FLY
F004-H	18	1731.622	60.000	-563.374	0.0	86.4	no
F004-S	18	1726.547	60.000	-563.635	0.0	78.6	no
F005-H	18	1813.195	125.000	-563.073	0.0	150.0	FLY
F005-S	18	1817.549	125.000	-562.458	0.0	127.5	FLY
F006-H	18	1806.490	119.000	-563.482	0.0	135.9	FLY
F006-S	18	1720.395	60.000	-563.835	0.0	74.4	no
F007-H	18	1804.343	125.000	-564.127	0.0	37.8	FLY
F007-S	18	1716.028	60.000	-564.400	0.0	51.6	no
F008-H	18	1812.440	125.000	-564.403	0.0	57.3	FLY
F008-S	18	1811.932	125.000	-563.862	0.0	54.0	FLY
F009-H	18	1816.198	115.000	-564.184	0.0	82.2	FLY
F009-S	18	1818.907	125.000	-563.197	0.0	150.0	FLY
F010-H	18	1815.771	105.000	-564.092	0.0	66.6	FLY
F010-S	18	1724.051	60.000	-564.198	0.0	67.8	no
F011-H	18	1800.160	125.000	-563.951	0.0	33.3	FLY
F011-S	18	1719.710	60.000	-564.246	0.0	48.6	no
F012-H	18	1727.439	60.000	-564.014	0.0	65.4	no
F012-S	18	1713.558	60.000	-563.565	0.0	94.5	no
F013-H	18	1835.381	125.000	-563.571	0.0	96.3	FLY
F013-S	18	1726.184	60.000	-564.352	0.0	140.4	no
F014-H	18	1807.353	125.000	-564.225	0.0	68.7	FLY
F014-S	18	1812.412	125.000	-564.056	0.0	76.2	FLY
F015-H	18	1807.102	125.000	-563.666	0.0	81.9	FLY
F015-S	18	1717.559	60.000	-563.009	0.0	121.8	no
F016-H	18	1811.586	125.000	-564.219	0.0	45.3	FLY
F016-S	18	1820.588	125.000	-563.963	0.0	51.9	FLY
F017-H	18	1822.019	113.000	-564.454	0.0	75.9	FLY
F017-S	18	1820.138	111.000	-563.288	0.0	79.8	FLY

185

F018-H	18	1805.453	95.000	-564.028	0.0	64.8	FLY
F018-S	18	1820.957	125.000	-564.183	0.0	45.9	FLY
F019-H	18	1718.427	60.000	-563.443	90.0	67.8	m/b
F019-S	18	1829.740	125.000	-562.935	0.0	117.3	FLY
F020-H	18	1712.891	60.000	-564.413	0.0	74.7	no
F020-S	18	1798.792	125.000	-564.305	0.0	81.3	FLY
F021-H	18	1821.224	125.000	-563.448	0.0	87.9	FLY
F021-S	18	1724.750	60.000	-563.526	0.0	78.6	no
F022-H	18	1713.531	60.000	-563.166	0.0	104.4	no
F022-S	18	1716.619	60.000	-563.941	60.0	80.7	m/b
F023-H	18	1814.101	119.000	-564.002	0.0	66.9	FLY
F023-S	18	1722.598	60.000	-563.290	0.0	99.9	no
F024-H	18	1821.702	83.000	-564.417	0.0	47.7	FLY
F024-S	18	1714.809	60.000	-564.274	0.0	36.9	no
F025-H	18	1724.717	60.000	-564.044	0.0	80.7	no
F025-S	18	1721.003	60.000	-563.823	0.0	78.9	no
F026-H	18	1716.081	60.000	-563.497	0.0	78.3	no
F026-S	18	1713.650	60.000	-564.434	0.0	69.6	no
F027-H	18	1808.123	125.000	-564.078	0.0	58.5	FLY
F027-S	18	1720.782	60.000	-563.451	0.0	73.2	no
F028-H	18	1717.228	60.000	-564.134	90.0	65.1	m/b
F028-S	18	1726.137	60.000	-563.973	90.0	115.8	m/b
F029-H	18	1805.843	79.000	-564.201	0.0	72.3	FLY
F029-S	18	1711.082	60.000	-563.515	0.0	63.9	no
F030-H	18	1716.683	60.000	-563.634	0.0	76.5	no
F030-S	18	1720.610	60.000	-563.980	0.0	55.5	no
F031-H	18	1817.762	60.000	-564.425	0.0	42.3	no
F031-S	18	1717.159	60.000	-564.436	0.0	77.7	no
F032-H	18	1802.806	60.000	-564.153	0.0	57.6	no
F032-S	18	1714.234	60.000	-564.363	0.0	103.2	no
F033-H	18	1837.149	125.000	-563.207	0.0	121.5	FLY
F033-S	18	1721.156	60.000	-564.000	0.0	129.9	no
F034-H	18	1715.971	60.000	-564.357	0.0	132.9	no
F034-S	18	1716.401	60.000	-562.769	0.0	115.2	no
F035-H	18	1720.734	60.000	-563.917	90.0	45.0	m/b
F035-S	18	1723.933	60.000	-564.436	90.0	45.0	m/b
F036-H	18	1821.950	60.000	-564.455	0.0	31.2	no
F036-S	18	1714.108	60.000	-564.303	0.0	31.5	no
F037-H	18	1809.728	103.000	-562.797	0.0	103.2	FLY
F037-S	18	1715.601	60.000	-563.843	0.0	117.0	no
F038-H	18	1820.393	60.000	-563.958	0.0	67.8	no
F038-S	18	1732.399	60.000	-564.436	0.0	70.8	no
F040-H	18	1713.213	60.000	-564.040	0.0	60.9	no
F040-S	18	1719.525	60.000	-564.037	0.0	57.9	no
F041-H	18	1718.990	60.000	-564.036	0.0	46.2	no
F041-S	18	1718.575	60.000	-564.051	0.0	67.5	no
F042-H	18	1703.351	60.000	-564.476	0.0	50.7	no
F042-S	18	1722.897	60.000	-563.759	0.0	57.6	no
F043-H	18	1824.325	125.000	-564.371	0.0	57.3	FLY
F043-S	18	1723.793	60.000	-564.096	0.0	39.6	no
H001-H	18	1722.127	60.000	-563.892	0.0	72.9	no
H002-H	18	1818.128	109.000	-564.375	0.0	55.8	FLY
H003-H	18	1830.432	125.000	-564.354	0.0	91.5	FLY
I001-H	18	1818.098	95.000	-564.067	0.0	100.8	FLY
I001-S	18	1715.111	60.000	-563.491	0.0	86.1	no
P001-H	18	1805.214	60.000	-564.474	0.0	69.3	no
P001-S	18	1716.215	60.000	-563.652	90.0	83.4	m/b
P002-H	18	1831.277	102.000	-563.681	0.0	68.4	FLY
P002-S	18	1721.189	60.000	-564.365	0.0	78.9	no
P003-H	18	1720.260	60.000	-564.186	0.0	20.1	no

File	Room	X	Y	Z	Rotate	Speed	RESULT
P003-S	18	1726.145	60.000	-564.269	0.0	22.8	no
P004-H	18	1822.676	178.000	-564.382	0.0	73.5	FLY
P004-S	18	1824.835	114.000	-564.144	0.0	47.4	FLY
P005-H	18	1821.990	64.000	-564.054	0.0	36.3	FLY
P005-S	18	1822.507	176.000	-563.778	0.0	70.8	FLY
P006-H	18	1718.519	60.000	-563.799	0.0	81.9	no
P006-S	18	1834.389	126.000	-564.157	0.0	56.7	FLY
P007-H	18	1721.718	60.000	-564.481	90.0	31.2	m/b
P007-S	18	1815.735	238.000	-564.479	0.0	42.6	FLY
P008-H	18	1727.620	60.000	-563.437	0.0	84.9	no
P008-S	18	1725.527	60.000	-564.308	0.0	120.9	no
P009-H	18	1804.290	128.000	-563.917	0.0	92.4	FLY
P009-S	18	1819.289	174.000	-564.091	0.0	137.4	FLY
P010-H	18	1736.918	60.000	-563.954	0.0	67.2	no
P010-S	18	1726.248	60.000	-564.445	0.0	61.5	no

Task Room 19 Reduced Data

File	Room	X	Y	Z	Rotate	Speed	RESULT
A001-H	19	2234.310	60.000	-674.933	0.0	57.3	no
A002-H	19	2233.182	60.000	-671.119	0.0	101.4	no
A003-H	19	2234.503	60.000	-669.012	0.0	45.0	no
A004-H	19	2233.936	60.000	-673.617	0.0	70.8	no
A005-H	19	2234.464	60.000	-671.617	0.0	70.2	no
B001-H	19	2234.739	60.000	-693.128	0.0	13.8	no
B001-S	19	2234.471	60.000	-687.853	90.0	36.3	ROTATE
B002-H	19	2233.956	60.000	-693.485	87.0	57.0	ROTATE
B002-S	19	2233.797	60.000	-683.448	90.0	78.3	ROTATE
B003-H	19	2234.345	60.000	-692.341	0.0	46.8	no
B003-S	19	2233.854	60.000	-689.350	0.0	80.1	no
B004-H	19	2234.474	60.000	-693.398	0.0	54.3	no
B004-S	19	2233.377	60.000	-690.714	90.0	81.6	ROTATE
B005-H	19	2234.471	60.000	-699.480	0.0	24.6	no
B005-S	19	2234.442	60.000	-691.106	0.0	47.7	no
F001-H	19	2234.728	60.000	-687.600	90.0	50.1	ROTATE
F001-S	19	2233.984	60.000	-685.315	90.0	62.4	ROTATE
F002-H	19	2234.594	60.000	-689.404	90.0	105.6	ROTATE
F002-S	19	2234.673	60.000	-694.429	6.0	62.1	no
F003-H	19	2233.975	60.000	-691.813	90.0	92.7	ROTATE
F003-S	19	2233.175	60.000	-691.206	90.0	105.9	ROTATE
F004-H	19	2233.580	60.000	-691.079	0.0	86.1	no
F004-S	19	2234.369	60.000	-689.411	0.0	100.8	no
F005-H	19	2234.587	60.000	-687.780	90.0	73.8	ROTATE
F005-S	19	2233.749	60.000	-687.618	90.0	112.5	ROTATE
F006-H	19	2233.802	60.000	-686.631	90.0	142.2	ROTATE
F006-S	19	2233.664	60.000	-687.683	66.0	76.5	ROTATE
F007-H	19	2234.674	60.000	-686.551	90.0	72.9	ROTATE
F007-S	19	2234.636	60.000	-689.254	90.0	67.2	ROTATE
F008-H	19	2234.012	60.000	-688.607	90.0	51.3	ROTATE
F008-S	19	2233.884	60.000	-690.063	90.0	60.0	ROTATE
F009-H	19	2234.425	60.000	-689.149	90.0	84.3	ROTATE
F009-S	19	2233.594	60.000	-689.772	81.0	150.0	ROTATE
F010-H	19	2234.105	60.000	-690.719	90.0	60.0	ROTATE
F010-S	19	2233.488	60.000	-688.059	24.0	98.1	ROTATE
F011-H	19	2234.679	60.000	-690.708	90.0	33.3	ROTATE
F011-S	19	2234.341	60.000	-688.793	90.0	44.1	ROTATE
F012-H	19	2234.744	60.000	-687.239	0.0	81.9	no
F012-S	19	2233.257	60.000	-685.900	0.0	97.2	no
F013-H	19	2233.723	60.000	-686.912	90.0	83.7	ROTATE
F013-S	19	2234.068	60.000	-686.588	0.0	144.3	no

F014-H	19	2234.676	60.000	-689.783	0.0	62.4	no
F014-S	19	2233.905	60.000	-689.410	0.0	60.3	no
F015-H	19	2234.150	60.000	-688.699	90.0	78.6	ROTATE
F015-S	19	2232.821	60.000	-687.317	90.0	122.4	ROTATE
F016-H	19	2234.192	60.000	-688.697	90.0	36.3	ROTATE
F016-S	19	2234.509	60.000	-687.217	90.0	45.6	ROTATE
F017-H	19	2234.139	60.000	-692.518	90.0	48.3	ROTATE
F017-S	19	2234.305	60.000	-691.002	75.0	66.9	ROTATE
F018-H	19	2234.128	60.000	-690.361	90.0	51.0	ROTATE
F018-S	19	2234.149	60.000	-688.124	90.0	51.0	ROTATE
F019-H	19	2234.163	60.000	-686.521	90.0	93.6	ROTATE
F019-S	19	2234.708	60.000	-683.620	66.0	77.7	ROTATE
F020-H	19	2234.487	60.000	-689.787	90.0	81.3	ROTATE
F020-S	19	2233.698	60.000	-688.106	90.0	82.8	ROTATE
F021-H	19	2233.965	60.000	-688.767	0.0	86.4	no
F021-S	19	2234.014	60.000	-688.640	0.0	90.3	no
F022-H	19	2233.547	60.000	-691.607	51.0	110.4	ROTATE
F022-S	19	2234.055	60.000	-692.665	90.0	84.9	ROTATE
F023-H	19	2234.352	60.000	-692.326	9.0	57.3	no
F023-S	19	2233.592	96.000	-689.370	0.0	100.5	m/b
F024-H	19	2234.365	60.000	-690.083	93.0	55.8	ROTATE
F024-S	19	2234.097	60.000	-687.092	90.0	54.0	ROTATE
F025-H	19	2233.776	60.000	-685.798	75.0	65.1	ROTATE
F025-S	19	2234.064	60.000	-688.703	57.0	73.5	ROTATE
F026-H	19	2233.309	60.000	-687.112	90.0	91.2	ROTATE
F026-S	19	2234.743	60.000	-688.799	90.0	91.5	ROTATE
F027-H	19	2234.422	60.000	-690.713	90.0	46.8	ROTATE
F027-S	19	2233.995	60.000	-688.016	0.0	112.8	no
F028-H	19	2234.022	60.000	-685.636	90.0	89.4	ROTATE
F028-S	19	2233.514	60.000	-686.244	69.0	113.4	ROTATE
F029-H	19	2233.806	60.000	-690.843	90.0	78.6	ROTATE
F029-S	19	2234.515	60.000	-690.103	90.0	59.4	ROTATE
F030-H	19	2234.385	60.000	-686.706	90.0	60.6	ROTATE
F030-S	19	2233.923	60.000	-687.878	90.0	52.8	ROTATE
F031-H	19	2234.037	60.000	-690.111	54.0	45.9	ROTATE
F031-S	19	2233.709	60.000	-689.862	90.0	73.8	ROTATE
F032-H	19	2233.994	60.000	-687.663	90.0	96.9	ROTATE
F032-S	19	2233.172	60.000	-687.836	90.0	113.4	ROTATE
F033-H	19	2233.467	60.000	-692.524	90.0	95.7	ROTATE
F033-S	19	2234.475	60.000	-688.598	0.0	146.1	no
F034-H	19	2234.692	60.000	-690.558	81.0	139.5	ROTATE
F034-S	19	2233.400	60.000	-691.080	90.0	116.7	ROTATE
F035-H	19	2234.076	60.000	-690.520	90.0	56.4	ROTATE
F035-S	19	2234.254	60.000	-690.281	90.0	48.6	ROTATE
F036-H	19	2234.440	60.000	-688.787	90.0	39.0	ROTATE
F036-S	19	2234.419	60.000	-689.919	45.0	23.7	ROTATE
F037-H	19	2234.374	60.000	-691.268	90.0	67.5	ROTATE
F037-S	19	2234.004	60.000	-685.104	90.0	131.4	ROTATE
F038-H	19	2233.689	60.000	-696.089	90.0	63.9	ROTATE
F038-S	19	2234.586	60.000	-701.520	90.0	65.1	ROTATE
F040-H	19	2233.927	60.000	-689.766	0.0	56.7	no
F040-S	19	2234.556	60.000	-688.036	0.0	49.2	no
F041-H	19	2234.260	60.000	-689.393	0.0	31.2	no
F041-S	19	2234.244	60.000	-686.877	90.0	70.8	ROTATE
F042-H	19	2234.644	60.000	-696.318	90.0	45.6	ROTATE
F042-S	19	2234.495	60.000	-688.807	0.0	44.7	no
F043-H	19	2234.153	60.000	-687.535	0.0	59.4	no
F043-S	19	2234.493	60.000	-689.652	90.0	49.5	ROTATE
H001-H	19	2234.025	60.000	-689.289	90.0	53.4	ROTATE
H002-H	19	2234.146	60.000	-698.621	0.0	43.2	no

File	Room	X	Y	Z	Rotate	Speed	RESULT
H003-H	19	2233.313	60.000	-692.588	90.0	87.9	ROTATE
I001-H	19	2233.416	60.000	-690.445	0.0	100.8	no
I001-S	19	2233.275	60.000	-695.166	90.0	96.6	ROTATE
P001-H	19	2234.458	60.000	-688.923	90.0	77.1	ROTATE
P001-S	19	2234.536	60.000	-687.478	90.0	79.5	ROTATE
P002-H	19	2233.967	60.000	-689.631	90.0	72.9	ROTATE
P002-S	19	2233.854	60.000	-692.237	78.0	82.5	ROTATE
P003-H	19	2234.537	60.000	-693.519	0.0	23.7	no
P003-S	19	2234.426	60.000	-690.843	63.0	33.0	ROTATE
P004-H	19	2234.101	192.000	-691.983	0.0	80.1	m/b
P004-S	19	2234.521	60.000	-688.625	87.0	34.2	ROTATE
P005-H	19	2234.395	60.000	-689.487	90.0	41.4	ROTATE
P005-S	19	2234.387	60.000	-688.654	90.0	38.1	ROTATE
P006-H	19	2234.137	60.000	-689.526	0.0	61.8	no
P006-S	19	2234.346	60.000	-688.211	0.0	62.7	no
P007-H	19	2234.206	60.000	-689.122	90.0	53.4	ROTATE
P007-S	19	2234.712	60.000	-687.782	90.0	45.6	ROTATE
P008-H	19	2233.854	60.000	-685.696	0.0	77.1	no
P008-S	19	2234.196	60.000	-694.212	0.0	140.1	no
P009-H	19	2233.756	60.000	-687.525	0.0	129.6	no
P009-S	19	2232.937	60.000	-690.846	0.0	130.8	no
P010-H	19	2234.064	60.000	-690.353	90.0	57.0	ROTATE
P010-S	19	2233.808	60.000	-687.157	0.0	63.0	no

Task Room 20 Reduced Data

File	Room	X	Y	Z	Rotate	Speed	RESULT
A001-H	20	2300.968	60.000	-221.677	0.0	46.5	not
A002-H	20	2306.853	60.000	-221.844	0.0	81.0	not
A003-H	20	2299.789	60.000	-221.876	0.0	45.6	not
A004-H	20	2306.714	60.000	-222.310	0.0	67.2	not
A005-H	20	2313.270	60.000	-221.990	0.0	51.0	not
B001-H	20	2414.520	60.000	-221.656	0.0	18.3	CATCH
B001-S	20	2307.806	60.000	-222.067	0.0	38.1	not
B002-H	20	2408.704	60.000	-221.938	0.0	55.8	CATCH
B002-S	20	2299.898	60.000	-222.113	0.0	106.2	not
B003-H	20	2428.827	60.000	-222.436	0.0	69.3	CATCH
B003-S	20	2299.192	60.000	-222.293	0.0	92.1	not
B004-H	20	2425.318	60.000	-221.738	0.0	47.7	CATCH
B004-S	20	2313.886	60.000	-222.015	0.0	89.7	not
B005-H	20	2352.154	60.000	-221.762	0.0	44.4	not
B005-S	20	2313.809	60.000	-221.678	0.0	36.3	not
F001-H	20	2301.917	60.000	-221.535	0.0	46.2	not
F001-S	20	2303.623	60.000	-221.958	0.0	89.7	not
F002-H	20	2365.694	60.000	-221.982	0.0	50.4	CATCH
F002-S	20	2311.994	60.000	-222.076	0.0	74.7	not
F003-H	20	2425.004	60.000	-222.314	0.0	82.5	CATCH
F003-S	20	2407.336	60.000	-223.026	0.0	135.3	CATCH
F004-H	20	2318.179	60.000	-222.630	0.0	91.8	not
F004-S	20	2318.113	60.000	-221.632	0.0	72.9	not
F005-H	20	2413.233	60.000	-222.768	0.0	119.7	CATCH
F005-S	20	2408.969	60.000	-222.881	0.0	118.5	CATCH
F006-H	20	2427.831	60.000	-223.602	0.0	140.1	CATCH
F006-S	20	2303.935	60.000	-221.532	0.0	94.8	not
F007-H	20	2305.809	60.000	-221.762	90.0	87.0	not
F007-S	20	2305.997	60.000	-221.794	0.0	84.9	not
F008-H	20	2302.260	60.000	-221.762	0.0	53.4	not
F008-S	20	2304.300	60.000	-221.965	0.0	41.1	not
F009-H	20	2318.638	60.000	-221.704	6.0	99.0	not
F009-S	20	2418.418	60.000	-221.987	24.0	148.8	CATCH

F010-H	20	2308.727	60.000	-222.045	0.0	83.1	not
F010-S	20	2425.194	60.000	-221.522	0.0	118.2	CATCH
F011-H	20	2304.357	60.000	-221.945	0.0	47.7	not
F011-S	20	2304.115	60.000	-222.232	0.0	67.5	not
F012-H	20	2310.541	60.000	-222.443	0.0	87.3	not
F012-S	20	2298.488	60.000	-222.745	0.0	103.8	not
F013-H	20	2326.435	60.000	-222.346	0.0	96.3	not
F013-S	20	2405.683	60.000	-221.585	0.0	136.5	CATCH
F014-H	20	2306.454	60.000	-222.676	0.0	78.9	not
F014-S	20	2311.726	60.000	-221.769	0.0	78.0	not
F015-H	20	2307.184	60.000	-221.836	0.0	76.5	not
F015-S	20	2308.289	60.000	-222.391	0.0	116.7	not
F016-H	20	2305.317	60.000	-221.626	90.0	25.5	not
F016-S	20	2308.413	60.000	-222.006	90.0	58.5	not
F017-H	20	2321.588	60.000	-221.837	0.0	49.5	not
F017-S	20	2331.574	60.000	-221.839	0.0	51.6	not
F018-H	20	2411.472	60.000	-221.573	0.0	44.4	CATCH
F018-S	20	2312.046	60.000	-222.302	0.0	59.1	not
F019-H	20	2309.477	60.000	-221.686	0.0	51.3	not
F019-S	20	2312.967	60.000	-221.900	0.0	102.0	not
F020-H	20	2412.358	60.000	-221.848	0.0	83.7	CATCH
F020-S	20	2305.219	60.000	-222.973	0.0	105.0	not
F021-H	20	2305.868	60.000	-222.542	0.0	81.3	not
F021-S	20	2308.239	60.000	-222.399	0.0	90.3	not
F022-H	20	2410.846	60.000	-222.174	0.0	77.1	CATCH
F022-S	20	2420.287	60.000	-222.191	0.0	67.8	CATCH
F023-H	20	2417.826	60.000	-221.777	0.0	40.8	CATCH
F023-S	20	2327.257	60.000	-222.699	0.0	86.1	not
F024-H	20	2312.825	60.000	-221.919	90.0	58.5	not
F024-S	20	2413.963	60.000	-222.256	0.0	66.6	CATCH
F025-H	20	2300.079	60.000	-222.110	0.0	81.9	not
F025-S	20	2299.129	60.000	-222.430	0.0	70.8	not
F026-H	20	2306.633	60.000	-221.992	0.0	78.3	not
F026-S	20	2308.377	60.000	-221.668	0.0	82.5	not
F027-H	20	2307.906	60.000	-221.928	0.0	87.9	not
F027-S	20	2305.931	60.000	-221.693	0.0	109.5	not
F028-H	20	2418.734	60.000	-221.697	0.0	77.7	CATCH
F028-S	20	2306.904	60.000	-222.566	0.0	127.8	not
F029-H	20	2416.388	60.000	-222.616	0.0	76.8	CATCH
F029-S	20	2302.468	60.000	-221.798	0.0	48.3	not
F030-H	20	2307.359	60.000	-222.607	0.0	75.6	not
F030-S	20	2301.653	60.000	-221.567	0.0	62.1	not
F031-H	20	2313.756	60.000	-221.856	0.0	57.9	not
F031-S	20	2309.525	60.000	-222.179	0.0	69.3	not
F032-H	20	2312.227	60.000	-222.810	0.0	106.8	not
F032-S	20	2310.200	60.000	-222.931	0.0	112.8	not
F033-H	20	2315.791	60.000	-222.734	0.0	89.1	not
F033-S	20	2304.862	60.000	-221.717	0.0	147.6	not
F034-H	20	2298.858	60.000	-222.079	0.0	146.7	not
F034-S	20	2307.215	60.000	-222.757	0.0	123.0	not
F035-H	20	2303.933	60.000	-221.696	90.0	55.2	not
F035-S	20	2307.095	60.000	-222.160	0.0	42.3	not
F036-H	20	2308.739	60.000	-221.930	0.0	40.8	not
F036-S	20	2304.169	60.000	-221.756	0.0	27.9	not
F037-H	20	2315.125	60.000	-221.573	0.0	56.4	not
F037-S	20	2314.187	60.000	-222.625	0.0	121.5	not
F038-H	20	2320.490	60.000	-221.777	0.0	80.4	not
F038-S	20	2322.967	60.000	-221.679	0.0	70.5	not
F040-H	20	2316.725	60.000	-221.545	0.0	58.8	not
F040-S	20	2311.227	60.000	-221.736	0.0	47.1	not

File	Room	X	Y	Z	Rotate	Speed	RESULT
F041-H	20	2408.536	60.000	-221.997	0.0	30.0	CATCH
F041-S	20	2411.473	60.000	-221.544	0.0	48.0	CATCH
F042-H	20	2310.454	60.000	-222.068	0.0	45.6	not
F042-S	20	2310.135	60.000	-221.920	0.0	48.0	not
F043-H	20	2313.666	60.000	-222.405	0.0	54.9	not
F043-S	20	2303.716	60.000	-221.555	0.0	54.6	not
H001-H	20	2308.571	60.000	-221.847	0.0	66.0	not
H002-H	20	2303.629	60.000	-221.874	0.0	46.2	not
H003-H	20	2301.686	60.000	-222.127	0.0	90.3	not
I001-H	20	2315.699	60.000	-222.834	0.0	108.0	not
I001-S	20	2439.189	60.000	-221.512	0.0	140.4	CATCH
P001-H	20	2314.066	60.000	-222.089	0.0	57.0	not
P001-S	20	2307.293	60.000	-221.630	36.0	66.3	not
P002-H	20	2312.597	60.000	-222.741	0.0	84.3	not
P002-S	20	2305.992	60.000	-221.570	0.0	115.2	not
P003-H	20	2294.086	60.000	-221.822	0.0	32.7	not
P003-S	20	2299.544	60.000	-221.559	0.0	31.5	not
P004-H	20	2309.783	60.000	-221.784	0.0	88.8	not
P004-S	20	2308.732	60.000	-222.039	0.0	37.2	not
P005-H	20	2306.174	60.000	-222.135	90.0	54.9	not
P005-S	20	2310.441	60.000	-221.536	81.0	62.1	not
P006-H	20	2437.174	60.000	-221.681	0.0	87.9	CATCH
P006-S	20	2300.220	60.000	-222.480	0.0	91.2	not
P007-H	20	2307.487	60.000	-221.719	0.0	30.9	not
P007-S	20	2300.946	60.000	-221.595	0.0	41.4	not
P008-H	20	2414.223	60.000	-221.911	0.0	55.8	CATCH
P008-S	20	2401.137	60.000	-221.756	0.0	113.4	CATCH
P009-H	20	2304.915	60.000	-222.577	0.0	93.9	not
P009-S	20	2303.186	60.000	-222.940	0.0	149.4	not
P010-H	20	2320.694	60.000	-221.962	0.0	68.4	not
P010-S	20	2315.165	60.000	-222.664	0.0	70.2	not

Task Room 21 Reduced Data

File	Room	X	Y	Z	Rotate	Speed	RESULT
A001-H	21	2823.500	125.000	-130.844	0.0	60.6	FLY
A002-H	21	2822.990	60.000	-22.575	0.0	117.9	no
A003-H	21	2823.850	60.000	-18.770	90.0	54.6	m/b
A004-H	21	2823.132	125.000	-128.117	0.0	80.4	FLY
A005-H	21	2824.244	125.000	-123.659	0.0	71.7	FLY
B001-H	21	2824.143	60.000	-34.758	0.0	17.1	no
B001-S	21	2823.797	60.000	-33.097	0.0	36.3	no
B002-H	21	2823.057	60.000	-22.951	0.0	79.8	no
B002-S	21	2822.913	60.000	-15.177	0.0	107.7	no
B003-H	21	2823.783	60.000	-31.175	0.0	54.3	no
B003-S	21	2824.001	103.000	-123.905	0.0	97.5	FLY
B004-H	21	2823.917	125.000	-134.015	0.0	53.7	FLY
B004-S	21	2824.201	125.000	-133.014	0.0	93.3	FLY
B005-H	21	2823.968	60.000	-40.078	0.0	31.5	no
B005-S	21	2824.174	60.000	-33.604	0.0	31.8	no
F001-H	21	2824.113	125.000	-123.836	0.0	35.4	FLY
F001-S	21	2823.995	125.000	-127.219	0.0	78.9	FLY
F002-H	21	2823.232	125.000	-143.341	0.0	65.7	FLY
F002-S	21	2823.501	60.000	-33.161	0.0	78.0	no
F003-H	21	2823.727	125.000	-137.722	0.0	113.4	FLY
F003-S	21	2823.399	125.000	-119.484	0.0	146.7	FLY
F004-H	21	2824.055	60.000	-23.310	0.0	93.3	no
F004-S	21	2823.692	60.000	-27.377	0.0	95.7	no
F005-H	21	2822.685	125.000	-135.549	0.0	121.2	FLY
F005-S	21	2822.221	125.000	-114.447	0.0	133.2	FLY

F006-H	21	2822.670	119.000	-131.914	0.0	146.7	FLY
F006-S	21	2824.177	125.000	-127.682	0.0	94.5	FLY
F007-H	21	2823.382	125.000	-127.038	0.0	63.6	FLY
F007-S	21	2822.507	125.000	-116.789	0.0	105.6	FLY
F008-H	21	2823.826	125.000	-120.421	0.0	53.1	FLY
F008-S	21	2824.174	125.000	-122.583	0.0	53.4	FLY
F009-H	21	2822.751	119.000	-119.152	0.0	126.9	FLY
F009-S	21	2823.261	98.000	-113.548	0.0	150.0	FLY
F010-H	21	2823.108	125.000	-133.159	0.0	77.1	FLY
F010-S	21	2823.881	60.000	-15.205	0.0	127.5	no
F011-H	21	2824.000	125.000	-124.858	0.0	34.8	FLY
F011-S	21	2823.302	60.000	-17.883	0.0	78.3	no
F012-H	21	2822.888	60.000	-36.157	0.0	89.1	no
F012-S	21	2823.560	125.000	-118.693	0.0	113.7	FLY
F013-H	21	2822.940	60.000	-24.662	0.0	91.8	no
F013-S	21	2823.463	60.000	-24.804	0.0	149.7	no
F014-H	21	2823.494	125.000	-123.874	0.0	58.5	FLY
F014-S	21	2823.365	125.000	-122.433	0.0	67.5	FLY
F015-H	21	2823.370	60.000	-35.714	0.0	84.6	no
F015-S	21	2822.815	125.000	-123.634	0.0	141.6	FLY
F016-H	21	2823.466	125.000	-124.351	0.0	49.8	FLY
F016-S	21	2823.229	81.000	-123.727	0.0	68.4	FLY
F017-H	21	2823.412	60.000	-122.555	90.0	54.0	m/b
F017-S	21	2823.655	73.000	-129.527	0.0	84.9	FLY
F018-H	21	2823.871	115.000	-130.772	0.0	50.4	FLY
F018-S	21	2823.875	125.000	-118.171	0.0	70.5	FLY
F019-H	21	2824.128	125.000	-135.806	0.0	53.7	FLY
F019-S	21	2823.471	99.000	-129.828	0.0	101.4	FLY
F020-H	21	2823.106	125.000	-120.495	0.0	84.6	FLY
F020-S	21	2824.245	125.000	-118.980	0.0	107.7	FLY
F021-H	21	2823.113	60.000	-18.164	0.0	77.1	no
F021-S	21	2822.545	125.000	-114.209	0.0	114.3	FLY
F022-H	21	2822.775	60.000	-31.484	0.0	93.3	no
F022-S	21	2823.030	60.000	-30.363	0.0	77.4	no
F023-H	21	2824.206	125.000	-115.042	0.0	58.8	FLY
F023-S	21	2823.442	60.000	-111.872	90.0	99.3	m/b
F024-H	21	2823.525	125.000	-137.223	0.0	51.0	FLY
F024-S	21	2823.789	60.000	-27.955	0.0	66.9	no
F025-H	21	2823.813	125.000	-124.893	0.0	61.8	FLY
F025-S	21	2823.090	125.000	-125.747	0.0	77.1	FLY
F026-H	21	2823.072	60.000	-26.934	0.0	75.3	no
F026-S	21	2823.637	125.000	-117.171	0.0	95.4	FLY
F027-H	21	2824.186	60.000	-29.965	0.0	85.5	no
F027-S	21	2824.127	125.000	-123.326	0.0	123.0	FLY
F028-H	21	2824.113	60.000	-32.282	90.0	37.8	m/b
F028-S	21	2822.881	60.000	-123.205	90.0	138.0	m/b
F029-H	21	2823.903	117.000	-116.163	0.0	74.7	FLY
F029-S	21	2823.416	125.000	-120.659	0.0	100.2	FLY
F030-H	21	2823.642	125.000	-131.352	0.0	91.2	FLY
F030-S	21	2823.379	125.000	-128.593	0.0	89.4	FLY
F031-H	21	2824.036	60.000	-30.045	0.0	54.3	no
F031-S	21	2823.952	125.000	-122.013	0.0	87.3	FLY
F032-H	21	2822.455	125.000	-132.992	0.0	120.3	FLY
F032-S	21	2824.248	119.000	-102.669	0.0	115.5	FLY
F033-H	21	2824.005	60.000	-30.284	0.0	145.2	no
F033-S	21	2823.821	124.000	-124.535	0.0	150.0	FLY
F034-H	21	2821.888	111.000	-134.820	0.0	146.7	FLY
F034-S	21	2823.978	126.000	-123.632	0.0	126.6	FLY
F035-H	21	2823.814	60.000	-30.670	90.0	79.8	m/b
F035-S	21	2823.775	83.000	-116.973	0.0	54.9	FLY

File	Room	X	Y	Z	Rotate	Speed	RESULT
F036-H	21	2823.384	125.000	-125.636	0.0	58.8	FLY
F036-S	21	2824.244	125.000	-123.294	0.0	43.8	FLY
F037-H	21	2823.807	60.000	-27.520	0.0	104.4	no
F037-S	21	2823.605	109.000	-131.283	0.0	129.6	FLY
F038-H	21	2823.969	60.000	-126.009	0.0	81.9	no
F038-S	21	2824.054	102.000	-116.274	0.0	74.4	FLY
F040-H	21	2823.886	125.000	-128.647	0.0	77.4	FLY
F040-S	21	2823.870	125.000	-114.805	0.0	54.0	FLY
F041-H	21	2823.827	60.000	-26.446	0.0	51.0	no
F041-S	21	2823.729	60.000	-117.838	0.0	72.6	no
F042-H	21	2824.235	60.000	-34.552	90.0	54.6	m/b
F042-S	21	2823.483	60.000	-29.325	0.0	47.4	no
F043-H	21	2823.990	60.000	-30.466	0.0	77.1	no
F043-S	21	2823.950	125.000	-127.731	0.0	69.9	FLY
H001-H	21	2822.789	60.000	-18.783	0.0	108.9	no
H002-H	21	2823.530	60.000	-128.928	0.0	59.4	no
H003-H	21	2823.806	60.000	-15.534	0.0	109.8	no
I001-H	21	2822.904	99.000	-132.566	0.0	108.9	FLY
I001-S	21	2823.747	123.000	-128.808	0.0	78.6	FLY
P001-H	21	2823.548	60.000	-36.446	0.0	80.4	no
P001-S	21	2824.044	166.000	-120.538	0.0	63.9	FLY
P002-H	21	2823.391	60.000	-35.954	0.0	72.3	no
P002-S	21	2824.011	60.000	-24.649	0.0	136.5	no
P003-H	21	2824.235	204.000	-114.833	0.0	27.0	FLY
P003-S	21	2824.192	60.000	-15.634	0.0	27.9	no
P004-H	21	2823.501	198.000	-123.022	0.0	84.0	FLY
P004-S	21	2824.004	60.000	-23.071	0.0	53.7	no
P005-H	21	2823.989	194.000	-119.542	0.0	47.7	FLY
P005-S	21	2823.063	222.000	-117.776	0.0	70.8	FLY
P006-H	21	2824.171	186.000	-133.314	0.0	53.1	FLY
P006-S	21	2823.265	142.000	-109.524	0.0	85.2	FLY
P007-H	21	2823.767	60.000	-36.739	0.0	42.0	no
P007-S	21	2823.765	60.000	-29.829	0.0	45.6	no
P008-H	21	2823.313	60.000	-28.569	0.0	75.9	no
P008-S	21	2823.792	60.000	-29.550	0.0	51.9	no
P009-H	21	2822.753	60.000	-32.115	0.0	139.2	no
P009-S	21	2822.765	114.000	-106.748	0.0	148.8	FLY
P010-H	21	2824.164	60.000	-25.785	0.0	60.0	no
P010-S	21	2824.118	60.000	-28.200	0.0	70.8	no

Task Room 22 Reduced Data

File	Room	X	Y	Z	Rotate	Speed	RESULT
A001-H	22	2952.427	60.000	-563.872	0.0	51.3	no
A002-H	22	2946.809	60.000	-563.168	0.0	138.3	no
A003-H	22	2947.121	60.000	-563.536	0.0	60.9	no
A004-H	22	2956.789	60.000	-563.813	0.0	85.8	no
A005-H	22	2950.083	60.000	-563.010	0.0	93.3	no
B001-H	22	2965.422	60.000	-564.345	0.0	20.7	no
B001-S	22	2965.515	60.000	-564.469	90.0	24.3	ROTATE
B002-H	22	2979.879	60.000	-563.717	90.0	81.0	ROTATE
B002-S	22	2971.787	60.000	-564.186	90.0	83.7	ROTATE
B003-H	22	2393.655	60.000	-563.895	0.0	46.5	no
B003-S	22	2966.589	60.000	-563.638	0.0	71.7	no
B004-H	22	2961.566	60.000	-563.651	0.0	61.5	no
B004-S	22	2965.220	60.000	-563.381	81.0	70.5	ROTATE
B005-H	22	2966.273	60.000	-564.060	0.0	43.8	no
B005-S	22	2966.240	60.000	-563.253	0.0	76.5	no
F001-H	22	2965.466	60.000	-564.220	90.0	24.6	ROTATE
F001-S	22	2967.067	60.000	-563.809	90.0	60.3	ROTATE

F002-H	22	2958.111	60.000	-563.986	90.0	75.6	ROTATE
F002-S	22	2970.015	60.000	-563.674	90.0	90.0	ROTATE
F003-H	22	2962.061	60.000	-564.186	90.0	84.3	ROTATE
F003-S	22	2962.943	60.000	-562.986	90.0	141.6	ROTATE
F004-H	22	2974.852	60.000	-564.006	0.0	97.2	no
F004-S	22	2968.130	60.000	-563.093	0.0	112.5	no
F005-H	22	2966.324	60.000	-563.883	90.0	88.8	ROTATE
F005-S	22	2972.083	60.000	-564.343	90.0	134.1	ROTATE
F006-H	22	2956.872	60.000	-563.379	93.0	146.7	ROTATE
F006-S	22	2968.404	60.000	-564.391	90.0	89.1	ROTATE
F007-H	22	2963.373	60.000	-563.949	90.0	54.0	ROTATE
F007-S	22	2966.086	60.000	-563.013	90.0	102.0	ROTATE
F008-H	22	2963.739	60.000	-563.928	90.0	39.9	ROTATE
F008-S	22	2964.292	98.000	-564.134	0.0	35.1	m/b
F009-H	22	2961.906	60.000	-564.069	90.0	114.3	ROTATE
F009-S	22	2958.607	60.000	-562.322	90.0	150.0	ROTATE
F010-H	22	2963.742	60.000	-564.268	90.0	50.7	ROTATE
F010-S	22	2982.016	60.000	-564.221	90.0	130.5	ROTATE
F011-H	22	2966.012	60.000	-564.452	90.0	43.2	ROTATE
F011-S	22	2966.864	60.000	-564.178	90.0	58.2	ROTATE
F012-H	22	2962.447	60.000	-563.597	0.0	94.5	no
F012-S	22	2965.832	60.000	-563.071	0.0	112.5	no
F013-H	22	2981.476	60.000	-563.607	90.0	94.2	ROTATE
F013-S	22	2972.070	60.000	-562.181	0.0	150.0	no
F014-H	22	2966.436	60.000	-563.952	0.0	56.4	no
F014-S	22	2967.666	60.000	-563.800	0.0	46.5	no
F015-H	22	2961.991	60.000	-563.333	90.0	89.4	ROTATE
F015-S	22	2967.225	60.000	-562.806	90.0	133.5	ROTATE
F016-H	22	2959.901	60.000	-564.386	90.0	39.0	ROTATE
F016-S	22	2968.608	60.000	-564.236	90.0	36.0	ROTATE
F017-H	22	2963.451	60.000	-564.021	90.0	42.3	ROTATE
F017-S	22	2967.615	60.000	-563.936	60.0	89.1	ROTATE
F018-H	22	2962.766	60.000	-563.852	90.0	42.9	ROTATE
F018-S	22	2968.873	60.000	-564.159	90.0	64.8	ROTATE
F019-H	22	2969.482	60.000	-564.340	90.0	62.1	ROTATE
F019-S	22	2964.419	60.000	-563.976	75.0	120.9	ROTATE
F020-H	22	2962.224	60.000	-564.228	90.0	81.9	ROTATE
F020-S	22	2969.871	60.000	-563.027	90.0	116.1	ROTATE
F021-H	22	2977.573	60.000	-563.323	90.0	83.1	ROTATE
F021-S	22	2963.451	60.000	-563.229	0.0	120.6	no
F022-H	22	2962.768	60.000	-563.591	90.0	104.1	ROTATE
F022-S	22	2973.725	60.000	-563.455	63.0	93.0	ROTATE
F023-H	22	2980.034	60.000	-563.646	0.0	70.8	no
F023-S	22	2968.715	60.000	-564.000	0.0	44.4	no
F024-H	22	2961.241	60.000	-563.861	90.0	51.6	ROTATE
F024-S	22	2963.365	60.000	-563.934	90.0	64.2	ROTATE
F025-H	22	2968.510	60.000	-564.351	90.0	76.8	ROTATE
F025-S	22	2967.362	60.000	-564.265	0.0	81.0	no
F026-H	22	2962.866	60.000	-563.787	90.0	80.1	ROTATE
F026-S	22	2967.516	60.000	-562.947	90.0	104.7	ROTATE
F027-H	22	2966.800	60.000	-564.236	90.0	72.3	ROTATE
F027-S	22	2969.208	60.000	-563.760	54.0	109.8	ROTATE
F028-H	22	2962.319	60.000	-563.426	90.0	68.7	ROTATE
F028-S	22	2965.803	60.000	-564.457	84.0	150.0	ROTATE
F029-H	22	2959.647	60.000	-564.230	90.0	87.9	ROTATE
F029-S	22	2967.731	60.000	-564.447	90.0	48.3	ROTATE
F030-H	22	2964.014	60.000	-563.815	90.0	86.1	ROTATE
F030-S	22	2969.801	60.000	-563.756	90.0	87.9	ROTATE
F031-H	22	2963.032	60.000	-564.182	87.0	38.7	ROTATE
F031-S	22	2967.378	60.000	-563.767	48.0	72.6	ROTATE

File	Room	X	Y	Z	Rotate	Speed	RESULT
F032-H	22	2965.665	60.000	-563.103	90.0	114.9	ROTATE
F032-S	22	2965.000	60.000	-564.205	90.0	125.1	ROTATE
F033-H	22	2972.583	60.000	-562.844	90.0	135.9	ROTATE
F033-S	22	2969.069	60.000	-564.367	0.0	132.0	no
F034-H	22	2956.455	60.000	-563.249	90.0	120.6	ROTATE
F034-S	22	2965.241	60.000	-563.859	81.0	113.4	ROTATE
F035-H	22	2967.721	60.000	-563.963	90.0	102.0	ROTATE
F035-S	22	2968.572	60.000	-564.006	90.0	44.4	ROTATE
F036-H	22	2966.112	60.000	-564.245	90.0	66.6	ROTATE
F036-S	22	2965.672	60.000	-564.270	54.0	38.4	ROTATE
F037-H	22	2958.912	60.000	-563.640	90.0	127.2	ROTATE
F037-S	22	2969.933	60.000	-564.056	90.0	129.0	ROTATE
F038-H	22	2976.086	60.000	-563.961	27.0	71.1	ROTATE
F038-S	22	2973.047	60.000	-563.411	90.0	77.4	ROTATE
F040-H	22	2962.831	60.000	-563.341	90.0	72.6	ROTATE
F040-S	22	2970.194	60.000	-564.440	90.0	62.1	ROTATE
F041-H	22	2971.829	60.000	-564.323	0.0	64.8	no
F041-S	22	2964.954	60.000	-563.630	81.0	94.5	ROTATE
F042-H	22	2960.038	60.000	-564.469	90.0	60.9	ROTATE
F042-S	22	2966.296	60.000	-563.809	0.0	59.1	no
F043-H	22	2964.652	60.000	-563.849	0.0	45.0	no
F043-S	22	2969.653	60.000	-564.378	90.0	62.4	ROTATE
H001-H	22	2968.959	60.000	-564.433	90.0	86.1	ROTATE
H002-H	22	2968.491	60.000	-563.745	0.0	69.3	no
H003-H	22	2961.708	60.000	-562.852	90.0	120.3	ROTATE
I001-H	22	2961.843	60.000	-563.889	36.0	76.8	ROTATE
I001-S	22	2963.992	60.000	-563.753	81.0	96.6	ROTATE
P001-H	22	2964.661	60.000	-564.048	90.0	83.4	ROTATE
P001-S	22	2967.095	60.000	-563.330	90.0	90.6	ROTATE
P002-H	22	2964.895	60.000	-563.784	90.0	56.7	ROTATE
P002-S	22	2976.147	60.000	-564.436	90.0	132.0	ROTATE
P003-H	22	2965.696	60.000	-564.402	0.0	35.1	no
P003-S	22	2968.864	60.000	-564.219	90.0	30.3	ROTATE
P004-H	22	2959.426	60.000	-564.393	90.0	80.4	ROTATE
P004-S	22	2964.816	60.000	-563.983	72.0	45.0	ROTATE
P005-H	22	2967.846	60.000	-564.240	90.0	45.0	ROTATE
P005-S	22	2970.775	60.000	-564.470	90.0	39.3	ROTATE
P006-H	22	2968.035	60.000	-563.491	0.0	101.4	no
P006-S	22	2963.388	60.000	-563.706	0.0	89.1	no
P007-H	22	2974.674	60.000	-564.420	90.0	35.7	ROTATE
P007-S	22	2970.590	60.000	-564.259	90.0	32.7	ROTATE
P008-H	22	2967.889	60.000	-563.897	0.0	59.4	no
P008-S	22	2970.906	60.000	-562.727	0.0	110.7	no
P009-H	22	2962.952	60.000	-562.738	0.0	150.0	no
P009-S	22	2966.646	60.000	-564.319	0.0	142.5	no
P010-H	22	2969.954	60.000	-563.568	90.0	74.1	ROTATE
P010-S	22	2972.250	60.000	-563.834	39.0	64.8	ROTATE

Task Room 23 Reduced Data

File	Room	X	Y	Z	Rotate	Speed	RESULT
A001-H	23	3412.803	60.000	-609.287	0.0	67.5	not
A002-H	23	3413.700	60.000	-626.752	0.0	122.7	not
A003-H	23	3413.063	60.000	-617.006	0.0	55.2	not
A004-H	23	3413.633	60.000	-633.740	0.0	60.3	not
A005-H	23	3412.712	60.000	-623.911	0.0	70.5	not
B001-H	23	3413.706	60.000	-737.003	0.0	14.1	CATCH
B001-S	23	3413.627	60.000	-726.988	0.0	35.4	CATCH
B002-H	23	3413.628	60.000	-735.318	0.0	66.0	CATCH
B002-S	23	3412.340	60.000	-732.273	0.0	95.4	CATCH

B003-H	23	3413.168	60.000	-733.253	0.0	46.5	CATCH
B003-S	23	3413.608	60.000	-733.339	0.0	73.2	CATCH
B004-H	23	3413.190	60.000	-741.513	0.0	60.9	CATCH
B004-S	23	3412.898	60.000	-734.183	0.0	87.9	CATCH
B005-H	23	3413.661	60.000	-638.180	0.0	36.9	not
B005-S	23	3413.468	60.000	-723.120	0.0	31.5	CATCH
F001-H	23	3413.154	60.000	-732.510	0.0	43.5	CATCH
F001-S	23	3413.307	60.000	-731.785	0.0	63.0	CATCH
F002-H	23	3412.527	60.000	-737.037	0.0	82.5	CATCH
F002-S	23	3412.937	60.000	-728.053	0.0	52.5	CATCH
F003-H	23	3413.726	60.000	-729.652	0.0	86.7	CATCH
F003-S	23	3413.297	60.000	-719.854	0.0	100.5	CATCH
F004-H	23	3412.976	60.000	-719.252	0.0	96.3	CATCH
F004-S	23	3411.970	60.000	-724.463	0.0	119.1	CATCH
F005-H	23	3413.357	60.000	-724.467	0.0	63.9	CATCH
F005-S	23	3412.885	60.000	-725.418	0.0	131.4	CATCH
F006-H	23	3413.666	60.000	-733.648	0.0	143.7	CATCH
F006-S	23	3412.711	60.000	-727.522	0.0	96.0	CATCH
F007-H	23	3413.636	60.000	-725.671	90.0	63.9	CATCH
F007-S	23	3413.409	60.000	-721.586	0.0	103.2	CATCH
F008-H	23	3413.446	60.000	-733.933	0.0	48.3	CATCH
F008-S	23	3413.707	60.000	-731.439	0.0	45.6	CATCH
F009-H	23	3411.910	60.000	-734.006	90.0	118.2	CATCH
F009-S	23	3412.782	60.000	-722.535	0.0	150.0	CATCH
F010-H	23	3412.700	60.000	-725.512	0.0	79.8	CATCH
F010-S	23	3413.344	60.000	-733.307	0.0	64.2	CATCH
F011-H	23	3413.733	60.000	-737.619	0.0	39.0	CATCH
F011-S	23	3412.952	60.000	-730.686	0.0	64.2	CATCH
F012-H	23	3413.310	60.000	-729.126	0.0	91.2	CATCH
F012-S	23	3412.838	60.000	-721.655	0.0	126.0	CATCH
F013-H	23	3412.999	60.000	-730.212	0.0	93.0	CATCH
F013-S	23	3413.538	60.000	-723.399	0.0	139.5	CATCH
F014-H	23	3413.569	60.000	-730.651	0.0	58.5	CATCH
F014-S	23	3412.954	60.000	-731.557	0.0	53.7	CATCH
F015-H	23	3413.528	60.000	-730.480	90.0	68.7	CATCH
F015-S	23	3412.550	60.000	-723.447	0.0	148.2	CATCH
F016-H	23	3413.309	60.000	-615.870	90.0	34.2	not
F016-S	23	3413.347	60.000	-628.159	0.0	41.7	not
F017-H	23	3412.969	60.000	-735.409	0.0	49.2	CATCH
F017-S	23	3413.437	60.000	-728.795	0.0	71.7	CATCH
F018-H	23	3413.350	60.000	-727.340	0.0	37.2	CATCH
F018-S	23	3413.607	60.000	-727.676	0.0	73.2	CATCH
F019-H	23	3413.117	60.000	-729.074	0.0	65.7	CATCH
F019-S	23	3412.464	60.000	-730.114	0.0	121.8	CATCH
F020-H	23	3413.530	60.000	-731.063	0.0	84.3	CATCH
F020-S	23	3412.455	60.000	-726.862	0.0	113.4	CATCH
F021-H	23	3413.501	60.000	-729.445	0.0	81.3	CATCH
F021-S	23	3412.014	60.000	-726.070	0.0	117.3	CATCH
F022-H	23	3412.832	60.000	-731.270	0.0	87.9	CATCH
F022-S	23	3412.985	60.000	-733.388	0.0	88.8	CATCH
F023-H	23	3413.663	60.000	-738.081	0.0	59.4	CATCH
F023-S	23	3413.218	60.000	-735.656	0.0	47.7	CATCH
F024-H	23	3412.783	60.000	-738.119	90.0	57.6	CATCH
F024-S	23	3413.377	60.000	-735.212	0.0	71.4	CATCH
F025-H	23	3413.565	60.000	-731.121	0.0	61.8	CATCH
F025-S	23	3412.915	60.000	-731.378	0.0	81.0	CATCH
F026-H	23	3413.342	60.000	-729.595	0.0	74.1	CATCH
F026-S	23	3413.257	60.000	-732.178	0.0	90.3	CATCH
F027-H	23	3413.738	60.000	-729.718	0.0	75.6	CATCH
F027-S	23	3413.518	60.000	-731.193	0.0	103.5	CATCH

File	Room	X	Y	Z	Rotate	Speed	RESULT
F028-H	23	3413.684	60.000	-732.483	0.0	87.0	CATCH
F028-S	23	3413.571	60.000	-727.631	0.0	111.6	CATCH
F029-H	23	3413.408	60.000	-620.767	0.0	36.9	not
F029-S	23	3413.725	60.000	-733.311	0.0	51.3	CATCH
F030-H	23	3412.835	60.000	-732.797	0.0	77.1	CATCH
F030-S	23	3413.556	60.000	-728.394	0.0	59.1	CATCH
F031-H	23	3413.338	60.000	-731.842	0.0	27.9	CATCH
F031-S	23	3412.826	60.000	-728.996	0.0	56.1	CATCH
F032-H	23	3412.504	60.000	-727.479	0.0	109.2	CATCH
F032-S	23	3412.664	60.000	-729.679	0.0	114.9	CATCH
F033-H	23	3412.624	60.000	-739.515	0.0	132.6	CATCH
F033-S	23	3413.391	60.000	-729.508	0.0	133.2	CATCH
F034-H	23	3413.031	60.000	-733.059	0.0	113.7	CATCH
F034-S	23	3413.557	60.000	-733.591	0.0	121.8	CATCH
F035-H	23	3413.518	60.000	-729.258	90.0	39.6	CATCH
F035-S	23	3413.339	60.000	-727.453	0.0	47.7	CATCH
F036-H	23	3413.493	60.000	-728.153	0.0	43.2	CATCH
F036-S	23	3413.325	60.000	-734.150	0.0	28.2	CATCH
F037-H	23	3413.241	60.000	-736.347	0.0	78.3	CATCH
F037-S	23	3412.162	60.000	-731.955	0.0	123.3	CATCH
F038-H	23	3413.284	60.000	-746.134	0.0	55.2	CATCH
F038-S	23	3412.974	60.000	-738.329	0.0	65.1	CATCH
F040-H	23	3412.936	60.000	-732.470	0.0	63.3	CATCH
F040-S	23	3413.396	60.000	-732.588	0.0	48.6	CATCH
F041-H	23	3413.672	60.000	-734.617	0.0	19.2	CATCH
F041-S	23	3413.343	60.000	-722.990	0.0	85.2	CATCH
F042-H	23	3413.314	60.000	-742.201	0.0	47.4	CATCH
F042-S	23	3413.114	60.000	-732.177	0.0	48.0	CATCH
F043-H	23	3413.427	60.000	-729.276	0.0	48.3	CATCH
F043-S	23	3413.556	60.000	-728.567	0.0	56.4	CATCH
H001-H	23	3413.152	60.000	-737.563	0.0	64.5	CATCH
H002-H	23	3413.220	60.000	-740.166	0.0	54.3	CATCH
H003-H	23	3412.773	60.000	-736.968	0.0	100.2	CATCH
I001-H	23	3413.455	60.000	-725.894	90.0	66.9	CATCH
I001-S	23	3412.642	60.000	-716.863	90.0	117.0	CATCH
P001-H	23	3412.795	60.000	-728.618	0.0	69.0	CATCH
P001-S	23	3413.050	60.000	-727.161	0.0	59.4	CATCH
P002-H	23	3413.697	60.000	-731.308	0.0	51.6	CATCH
P002-S	23	3412.805	60.000	-729.771	0.0	101.1	CATCH
P003-H	23	3413.308	60.000	-750.255	0.0	30.6	CATCH
P003-S	23	3413.551	60.000	-730.164	0.0	33.0	CATCH
P004-H	23	3413.520	60.000	-740.026	0.0	68.4	CATCH
P004-S	23	3413.467	60.000	-733.513	0.0	38.4	CATCH
P005-H	23	3413.148	60.000	-735.435	90.0	36.0	CATCH
P005-S	23	3413.749	60.000	-728.361	90.0	31.8	CATCH
P006-H	23	3413.279	60.000	-748.359	0.0	83.7	CATCH
P006-S	23	3413.400	60.000	-734.718	0.0	50.1	CATCH
P007-H	23	3412.936	60.000	-734.974	0.0	53.7	CATCH
P007-S	23	3413.223	60.000	-729.072	0.0	49.2	CATCH
P008-H	23	3413.345	60.000	-735.083	0.0	50.4	CATCH
P008-S	23	3413.371	60.000	-699.069	0.0	52.8	CATCH
P009-H	23	3412.848	60.000	-725.902	0.0	87.6	CATCH
P009-S	23	3412.552	60.000	-617.514	0.0	148.2	not
P010-H	23	3412.835	60.000	-729.041	0.0	69.9	CATCH
P010-S	23	3413.641	60.000	-732.239	0.0	63.9	CATCH

Task Room 24 Reduced Data

File	Room	X	Y	Z	Rotate	Speed	RESULT
A001-H	24	3527.808	125.000	-222.303	0.0	65.7	FLY

A002-H	24	3614.785	60.000	-222.172	0.0	84.3	no
A003-H	24	3621.653	60.000	-221.544	0.0	47.4	no
A004-H	24	3529.940	125.000	-221.729	0.0	63.9	FLY
A005-H	24	3610.614	60.000	-222.093	0.0	62.1	no
B001-H	24	3621.646	60.000	-221.596	0.0	17.1	no
B001-S	24	3608.694	60.000	-221.956	0.0	31.5	no
B002-H	24	3609.882	60.000	-221.613	0.0	34.8	no
B002-S	24	3515.937	108.000	-222.223	0.0	115.2	FLY
B003-H	24	3532.190	109.000	-222.008	0.0	61.8	FLY
B003-S	24	3517.995	125.000	-222.657	0.0	81.0	FLY
B004-H	24	3621.573	60.000	-221.771	0.0	55.2	no
B004-S	24	3517.373	125.000	-221.919	0.0	81.3	FLY
B005-H	24	3618.268	60.000	-221.748	0.0	39.6	no
B005-S	24	3616.771	60.000	-221.564	0.0	56.7	no
F001-H	24	3524.996	125.000	-221.698	0.0	50.7	FLY
F001-S	24	3513.189	125.000	-222.045	0.0	55.8	FLY
F002-H	24	3614.209	60.000	-222.849	0.0	89.1	no
F002-S	24	3527.707	125.000	-222.638	0.0	95.7	FLY
F003-H	24	3538.847	125.000	-221.940	0.0	110.4	FLY
F003-S	24	3518.154	125.000	-223.367	0.0	134.4	FLY
F004-H	24	3608.488	60.000	-221.764	0.0	92.4	no
F004-S	24	3620.530	60.000	-221.602	0.0	121.2	no
F005-H	24	3524.941	125.000	-222.674	0.0	90.0	FLY
F005-S	24	3523.235	125.000	-221.802	0.0	134.4	FLY
F006-H	24	3616.396	60.000	-222.350	0.0	126.9	no
F006-S	24	3522.286	125.000	-221.573	0.0	94.2	FLY
F007-H	24	3615.441	60.000	-221.519	90.0	60.0	m/b
F007-S	24	3609.816	60.000	-221.702	0.0	111.6	no
F008-H	24	3521.847	125.000	-221.785	0.0	65.1	FLY
F008-S	24	3515.995	125.000	-221.553	0.0	42.9	FLY
F009-H	24	3539.649	125.000	-223.733	0.0	138.9	FLY
F009-S	24	3521.466	104.000	-223.008	0.0	150.0	FLY
F010-H	24	3526.113	125.000	-222.131	0.0	71.1	FLY
F010-S	24	3527.419	125.000	-222.446	0.0	83.1	FLY
F011-H	24	3610.350	60.000	-221.560	0.0	49.2	no
F011-S	24	3605.366	60.000	-222.198	0.0	62.1	no
F012-H	24	3610.976	60.000	-221.553	0.0	88.2	no
F012-S	24	3610.442	60.000	-222.690	0.0	117.0	no
F013-H	24	3621.567	60.000	-222.822	0.0	94.5	no
F013-S	24	3621.461	60.000	-222.347	0.0	140.7	no
F014-H	24	3616.954	60.000	-221.922	0.0	94.5	no
F014-S	24	3621.528	60.000	-221.804	0.0	85.5	no
F015-H	24	3527.010	125.000	-221.979	0.0	55.2	FLY
F015-S	24	3513.110	125.000	-222.250	0.0	140.1	FLY
F016-H	24	3516.634	125.000	-221.672	0.0	26.4	FLY
F016-S	24	3526.666	125.000	-222.019	0.0	57.0	FLY
F017-H	24	3539.204	125.000	-222.003	0.0	50.1	FLY
F017-S	24	3527.092	125.000	-222.300	0.0	75.0	FLY
F018-H	24	3526.981	125.000	-222.191	0.0	45.3	FLY
F018-S	24	3515.304	125.000	-222.178	0.0	64.8	FLY
F019-H	24	3537.638	125.000	-222.285	0.0	61.8	FLY
F019-S	24	3540.807	125.000	-221.572	0.0	90.3	FLY
F020-H	24	3614.066	60.000	-222.148	0.0	84.9	no
F020-S	24	3608.272	60.000	-222.194	0.0	99.3	no
F021-H	24	3525.837	125.000	-221.767	0.0	96.6	FLY
F021-S	24	3520.116	116.000	-221.687	0.0	122.1	FLY
F022-H	24	3621.627	60.000	-221.803	0.0	86.1	no
F022-S	24	3621.652	60.000	-222.162	0.0	98.1	no
F023-H	24	3621.395	60.000	-222.369	0.0	55.8	no
F023-S	24	3619.814	60.000	-221.656	0.0	54.0	no

F024-H	24	3630.282	60.000	-221.782	90.0	61.5	m/b
F024-S	24	3612.648	60.000	-221.918	0.0	75.3	no
F025-H	24	3521.782	125.000	-221.972	0.0	57.6	FLY
F025-S	24	3621.649	60.000	-221.884	0.0	77.7	no
F026-H	24	3614.718	60.000	-221.690	0.0	76.2	no
F026-S	24	3613.401	60.000	-222.341	0.0	57.0	no
F027-H	24	3616.176	60.000	-221.756	0.0	68.1	no
F027-S	24	3621.650	60.000	-222.151	0.0	110.4	no
F028-H	24	3614.980	60.000	-222.021	90.0	91.5	m/b
F028-S	24	3618.945	60.000	-222.108	0.0	105.0	no
F029-H	24	3611.557	60.000	-221.649	0.0	47.4	no
F029-S	24	3618.791	60.000	-222.046	0.0	77.4	no
F030-H	24	3612.458	60.000	-221.778	0.0	75.0	no
F030-S	24	3612.579	60.000	-221.854	0.0	62.4	no
F031-H	24	3609.286	60.000	-221.868	0.0	47.7	no
F031-S	24	3614.161	60.000	-221.537	0.0	85.5	no
F032-H	24	3614.211	60.000	-222.441	0.0	113.4	no
F032-S	24	3537.137	125.000	-222.091	0.0	106.2	FLY
F033-H	24	3621.616	60.000	-223.306	0.0	139.5	no
F033-S	24	3621.535	60.000	-222.988	0.0	150.0	no
F034-H	24	3528.604	125.000	-221.512	0.0	115.2	FLY
F034-S	24	3527.158	108.000	-222.313	0.0	125.4	FLY
F035-H	24	3607.665	60.000	-221.950	90.0	46.5	m/b
F035-S	24	3615.040	60.000	-222.030	0.0	62.7	no
F036-H	24	3518.962	125.000	-221.829	0.0	36.9	FLY
F036-S	24	3519.441	125.000	-221.572	0.0	32.4	FLY
F037-H	24	3615.836	60.000	-222.491	90.0	96.6	m/b
F037-S	24	3615.448	60.000	-221.951	0.0	144.0	no
F038-H	24	3621.549	60.000	-222.192	0.0	80.4	no
F038-S	24	3621.579	60.000	-221.983	0.0	93.0	no
F040-H	24	3528.058	125.000	-221.626	0.0	59.7	FLY
F040-S	24	3613.119	60.000	-222.216	0.0	68.7	no
F041-H	24	3610.754	60.000	-221.668	0.0	22.5	no
F041-S	24	3615.973	60.000	-221.910	0.0	52.8	no
F042-H	24	3533.939	125.000	-222.308	0.0	60.3	FLY
F042-S	24	3526.739	117.000	-222.107	0.0	50.1	FLY
F043-H	24	3520.063	125.000	-221.551	0.0	58.8	FLY
F043-S	24	3520.841	125.000	-221.567	0.0	63.3	FLY
H001-H	24	3621.559	60.000	-221.515	0.0	69.0	no
H002-H	24	3542.260	125.000	-221.584	0.0	37.8	FLY
H003-H	24	3617.656	60.000	-222.150	0.0	79.5	no
I001-H	24	3524.427	93.000	-221.993	0.0	39.3	FLY
I001-S	24	3538.091	125.000	-221.665	0.0	108.9	FLY
P001-H	24	3534.124	126.000	-221.622	0.0	77.7	FLY
P001-S	24	3521.172	196.000	-221.613	0.0	116.1	FLY
P002-H	24	3537.322	250.000	-221.813	0.0	93.3	FLY
P002-S	24	3519.287	136.000	-222.083	0.0	111.6	FLY
P003-H	24	3621.649	60.000	-221.612	0.0	21.3	no
P003-S	24	3621.638	60.000	-221.654	0.0	29.1	no
P004-H	24	3545.076	250.000	-222.107	0.0	68.1	FLY
P004-S	24	3537.100	250.000	-221.505	0.0	39.3	FLY
P005-H	24	3526.463	192.000	-221.691	0.0	46.2	FLY
P005-S	24	3529.464	136.000	-221.506	0.0	95.1	FLY
P006-H	24	3621.648	60.000	-221.838	0.0	84.9	no
P006-S	24	3509.829	118.000	-222.354	0.0	78.0	FLY
P007-H	24	3625.727	60.000	-222.085	90.0	67.8	m/b
P007-S	24	3522.959	250.000	-222.190	0.0	44.1	FLY
P008-H	24	3621.600	60.000	-221.893	0.0	55.5	no
P008-S	24	3601.626	60.000	-222.937	0.0	94.8	no
P009-H	24	3525.577	158.000	-223.179	0.0	148.5	FLY

P009-S	24	3605.339	60.000	-221.535	0.0	85.2	no
P010-H	24	3621.644	60.000	-222.570	0.0	76.2	no
P010-S	24	3541.241	82.000	-222.251	0.0	63.9	FLY

LIST OF REFERENCES

Allard, F. (1999). <u>Course Notes: Information processing in human perceptual motor performance</u>. Waterloo, Ontario: Dept. of Kinesiology, University of Waterloo.

Anders, P. (1999). <u>Envisioning cyberspace: Designing 3D electronic spaces</u>. New York: McGraw-Hill.

Barfield, W. & Furness, T.A. (1995). <u>Virtual environments and advanced interface design</u>. New York, NY: Oxford University Press.

Bingham, G. & Muchisky, M. (1992). <u>Affordances and dynamics: Graspability and center of mass perception (Technical Report # 60).</u> Bloomington, IN: Indiana University, Program of Cognitive Science.

Barnard, P.J. & May, J. (1999). Representing cognitive activity in complex tasks. <u>Human-Computer Interaction, 14</u>, 93-159.

Box, G E.P., Hunter, W.G. & Hunter, J.S. (1974). <u>Statistics for experimenters</u>. New York: John Wiley and Sons.

Bregman, A.S. (1990). <u>Auditory scene analysis</u>. Cambridge, Massachusetts: MIT Press.

Cain, W.S. & Algom, D. (1997). Perceptual and mental mixtures in odor and in taste: are there similarities and differences between experiments or between modalities? <u>Journal of Experimental Psychology: Human Perception and Performance, 23</u>(5), 1588-1593.

Card, S.K., Moran T.P., & Newell, A. (1983). <u>The psychology of human-computer interaction</u>, Hillsdale, NJ: Lawrence Erlbaum Associates.

Cohn, J.V., DiZio, P., & Lackner, J.R. (2000). Reaching during virtual rotation: Context specific compensations for expected corilis effects. Journal of Neurophysiology, 83(6), 3230-40.

Curran, T., Schacter, D.L., & Galluccio, L. (1999). Cross-modal priming and explicit memory in patients with verbal production deficits. <u>Brain and Cognition, 29</u>, 133-146.

Cutting, J.E. (1997). How the eye measures reality and virtual reality. <u>Behavior Research Methods, Instruments and Computers, 29</u>(1), 27-36.

Cutting, J.E., Vishton, P.M., Fluckiger, M., & Baumberger, B. (1997). Heading and path information from retinal flow in naturalistic environments. <u>Perception and Psychophysics, 59</u>(3), 426-441.

Cutting, J.E., Wang, R.F., Fluckiger, M. & Baumberger, B. (1999). Human heading judgments and object-based motion information. Vision Research, 39, 1079-1105.

De Angeli, A. , Romary, L., & Wolff, F. (1999). Ecological Interfaces: Extending the Pointing Paradigm by Visual Context. CONTEXT 1999, 91-104.

Dixon, M. W., Wraga, M., Proffitt, D. R., & Williams, G. C. (2000). Eye height scaling of absolute size in immersive and nonimmersive displays. Journal of Experimental Psychology, 26(2), 582-593.

Durlach, N.I. & Mavor, A.S. (Eds.) (1995). Virtual reality - scientific and technological challenges. Washington, DC: National Academy Press.

Eberts, R. (1994). User interface design. Englewood Cliffs, NJ: Prentice Hall.

Eimer, M. (2001). Crossmodal links in spatial attention between vision, audition, and touch: Evidence from event-related brain potentials. Neuropsychologia, 29, 1292-1303.

Ellis, S.R. (1993). Pictorial communication in virtual and real environments. London: Taylor and Francis Press.

Fitzgerald, W. & Goldstein, E. (1997). Honesty of Affordance, A White Paper. Evanston, Illinois: Neodesic Corporation.

Flach, J.M. & Holden, J. (1998). The reality of experience: Gibson's way. Presence, 27(1), 90-95.

Flanagan, P., McAnally, K.I., Martin, R.L., Meehan, J.W. & Oldfield S.R. (1998). Aurally and visually guided visual search in a virtual environment. Human Factors, 40(3, 461-468.

Forgus, R.H. & Melamed, L.E. (1976). Perception: A cognitive-stage approach (2nd edition). New York: McGraw-Hill.

Freedland, R.L., & Dannermiller, J.L. (1987). Detection of stimulus motion in 5-month-old infants. Journal of Experimental Psychology: Human Perception and Performance, 13(4), 566-576.

Gibson, E.J. (1987, August). Introductory essay: What does infant perception tell us about theories of perception? Journal of Experimental Psychology: Human Perception and Performance, 13(4), 515-523.

Gibson, E.J. & Pick, A. D. (2000). An ecological approach to perceptual learning and development. New York, NY: Oxford University Press.

Gibson, E.J., Ricco, G., Schmuckler, M.A., Stoffregen, T.A., Rosenburg, D. , & Taormina, J. (1987, August). Detection of traversablity of surfaces by crawling and walking infants. Journal of Experimental Psychology: Human Perception and Performance, 13(4), 533-544.

Gibson, J.J. (1979/1986). The ecological approach to visual perception. Hillsdale, NJ: Lawrence Erbaum Associates.

Gibson, J.J. & Mowrer, O.H. (1938, July). Determinants of the perceived vertical and horizontal. Psychological Review, 300-323.

Gordon, I.E. (1989). Theories of visual perception. Chichester, UK: John Wiley and Sons.

Gossweiler, R., Profitt, D., Bhalla, M., & Paush, R. (1997). A Hill Study: Using a virtual environment as a perceptual psychology laboratory. http://www.cs.virigina.edu/~rg3/hill/hillPaperRevision.html

Grandjean, E. (1988). Fitting the task to the man: A textbook of occupational ergonomics (4th edition). New York: Taylor and Francis.

Gray, W.D. & Salzman, M.C. (1998). Damaged merchandise? A review of experiments that compare usability evaluation methods. Human-Computer Interaction, 13, 203-261.

Han, S.H., Williges, B.H., & Williges, R.C. (1997). A paradigm for sequential experimentation. Ergonomics, 40(7), 737-760.

Henneman, R.H., & Long, E.R. (1954). A Comparison of the visual and auditory senses as channels for data presentation. Technical Report No. 54-363. USAF, Wright Air Development Center, Dayton, Ohio.

Ijsselsteijn, W., Freeman, J., de Ridder, H., Avons, S.E., & Pearson, D. (2000, March). Towards an objective corroborative measure of presence: Postural responses to moving video. PRESENCE 2000 -- 3rd International Workshop on Presence, 27-28 March 2000.

Ivanenko, Y.P., Viaud-Delmon, I., Sigler, I., Israel, I., & Berthoz, A. (1998). The vestibulo-ocular reflex and angular displacement perception in darkness in humans: adaptation to a virtual environment. Neuroscience Letters, 241, 167-170.

Jul, S., & Furnas, G.W. (1997, October). Navigation in electronic worlds. ACM SIGCHI Bulletin, 29 (4), 44-49.

Kadunce, D. C., Vaughan, J. W., Wallace, M. T., & Stein B. E. (2001). The influence of visual and auditory receptive field organization on multisensory integration in t he superior colliculus. Experimental Brain Research, 139, 303-310.

Kalawsky, R. S. (1993). The science of virtual reality and virtual environments. Wokingham, England; Addison-Wesley.

Kalawsky, R.S. (2000, March). The validity of presence as a reliable human performance metric in immersive environments. Presence 2000 -- 3rd International Workshop on Presence, 27-28 March 2000.

Kellman, P.J., Gleitman, H. & Spelke, E.S. (1987, August). Object and observer motion in the perception of objects by infants. Journal of Experimental Psychology: Human Perception and Performance, 13(4), 586-593.

Kellman, P. J. & Short, K.R. (1987, August). Development of three-dimensional form perception. Journal of Experimental Psychology: Human Perception and Performance, 13(4), 545-557.

Kelso, J. A. S. (1995). Dynamic patterns: The self-organization of brain and behavior. Cambridge, MA: The MIT Press.

Kennedy, J.M. (1974). Perception, pictures, and the etcetera principle. In Robert B. MacLeod, and Herbert L. Pick, Jr. (Eds.), Perception: Essays in honor of James J. Gibson (pp 209-226). London: Cornell University Press.

Kennedy, R. S. & MCauley, M.E. (1984), The Motion History Questionnaire. Essex Corporation, Orlando, FL.

Kennedy, R. S., Lane, N. E., Berbaum, K. S., & Lilienthal, M. G. (1993) Simulator sickness questionnaire: An enhanced method for quantifying simulator sickness. The International Journal of Aviation Psychology, 3(3), 203-220.

Kensing F. & Munk-Madsen, A. (1993, June). Participatory Design: Structure in the Toolbox. Communications of the ACM, 36(4) 78-85.

Kolev, O., Mergner, T., Kimmig, & Becker, W. (1996). Detection thresholds for object motion and self-motion during vestibular and visuo-oculomotor stimulation. Brain Research Bulletin, 40(5/6), 451-458.

Kourtzi, Z. & Shiffrar, M. (1997). One-shot view invariance in a moving world. Psychological Science, 8(6), 461-465.

Kuhn, W. (1996). Formal models of common-sense geographic worlds, a proposal to NCGIA initiative 21. http://www.geog.buffalo.edu/ncgia/i21/papers/kuhn.html: Institute for Geoinformatics, University of Muenster, Germany.

Lampton, D.R., Knerr, B.W., Goldberg, S.L., Bliss, J.P., Moshell, J.M., & Blau, B.S. (1994). The virtual environment performance assessment battery (VEPAB): Development and evaluation. Presence, 3(2), 145-157.

Lee, D.H., & Reddish, P.E. (1981, 24 September). Plummeting gannets: A paradigm of ecological optics. Nature, 293, 293-294.

Lee, D.N., Young, D.S., Reddish, P.E., Lough, S., & Clayton, T.M.H. (1983). Visual timing when hitting an accelerating ball. Quarterly Journal of Experimental Psychology, 35a, 333-346.

Lintern, G. (2000). An affordance-based perspective on human-machine interface design. Ecological Psychology, 12(1), 65-69.

Lombard, M., & Ditton, T.B. (1997). At the heart of it all: The concept of presence. Journal of Computer-Mediated Communication, 3(2).

Marik, L. S. (1987, June). Eyeheight-scaled information about affordances: A study of sitting and stair climbing. Journal of Experimental Psychology: Human Perception and Performance, 13(3), 361-370.

Monder, T.A., & Amirault, K.J. (1998). Effect of same- and different-modality saptial cues on auditory and visual target identification. Journal of Experimental Psychology: Human Perception and Performance, 24(3), 745-755.

Norman, D.A. (1988). The design of everyday things. New York: Double Day.

Norman, D.A. (1993). The things that make us smart. New York: Addison-Wesley.

Okamoto, A. (1997). Toward rehabilitation cognitive engineering – gap between theory and practice in the human interface of information processing devices for people with disabilities. In M.L. Smith, G. Salvendy, and R.J. Koubek (Eds.), Design of computing systems: Social and ergonomics considerations (pp 551-554). New York: Elsevier Science.

Oudejans, R.R.D., Michaels, C.F., Bakker, F.C. & Dolne, M.A. (1996). The relevance of action in perceiving affordances: perception of catchableness of fly balls. Journal of Experimental Psychology: Human Perception and Performance, 22(4), 879-892.

Pausch, R., Shackelford, M. A., & Proffitt, D. (1993). A user study comparing head-mounted and stationary displays. 1993 IEEE Symposium on Research Frontiers in Virtual Reality, 41-45.

Pejtersen, A.M. & Rasmussen, J. (1997). Ecological information systems and support of learning: Coupling work domain information to user characteristics. In M. Helander, T.K. Landauer, and P.V. Prabhu, (Eds.), Handbook of Human-Computer Interaction (2nd edition) (pp. 49-63) Amsterdam: North-Holland.

Popescu, G.V., Burdea, G.C., & Trefftz, H. (2002). Multimodal interaction modeling. In K.M. Stanney (Ed.), Handbook of Virtual Environments: Design Implementation and Application (pp TBD). Mahwah, NJ: Lawrence-Erlbaum, Associates.

Pratt, D.R., Zyda, M., & Kelleher, K. (1995, July). Virtual reality in the mind of the beholder. Computer, 17-26.

Proctor, R.W., & Proctor, J.D. (1997). Sensation and perception. In G. Salvendy (Ed.), Handbook of human factors and ergonomics (Vol. 2, pp. 43-88). New York, NY: John Wiley and Sons.

Proffitt, D.R. & Kaiser, M.K. (1995). Human factors in virtual reality development. Tutorial at the Virtual Reality Annual International Symposium, March 11-15, Research Triangle, NC.

Readinger, W.O., Chatziastros, A., Cunningham, D.W., Bülthoff, H.H., & Cutting, J.E. (2002). Systematic effects of gaze-eccentricity on steering. Journal of Experimental Psychology: Applied, 4, 247-258.

Reber, A.S. (1995). The penguin dictionary of psychology (2nd edition). New York: Penguin Books.

Regan, D. (2000). <u>Human perception of objects</u>. Sunderland, MA: Sinauer Associates, Inc.

Regenbrecht, H.T., Schubert, T.W., & Friedmann, F. (1998). Measuring the sense of presence and its relations to fear of heights in virtual environments. <u>International Journal of Human-Computer Interaction, 10</u>(3), 233-248.

Rensink, R.A., O'Regan, J.K., & Clark, J.J. (1997). To see or not to see: The need for attention to perceive changes in scenes. <u>Psychological Science, 8</u>(5), 368-374.

Rode, S., Salkovskis, P.M., & Jack, T. (2001). An experimental study of attention, labeling, and memory in people suffering from chronic pain. <u>Pain, 94</u>, 193-203.

Rose, S.A., Jankowski, J.J & Senior, G.J. (1997). Infants' recognition of contour-deleted figures. <u>Journal of Experimental Psychology: Human Perception and Performance, 23</u>(4), 1206-1217.

Runeson, S. & Frykholm, G. (1981). Visual perception of lifted weight. <u>Journal of Experimental Psychology, 7</u>(4), 733-740.

St. Amant, R. (1999). User interface affordances in a planning representation. <u>Human-Computer Interaction, 14</u>, 317-355.

Sanocki, T. & Epstein, W. (September 1997). Priming spatial layout of scenes.<u> Psychological Science, 8</u>(5), 374-378.

Schöner, G. (1995). Recent developments and problems in human movement science and their conceptual implications. <u>Ecological Psychology 7</u>, 291-314.

Sharma, R., Pavlovic, V.I. & Huang, T.S. (May 1998). Toward multimodal human-computer interface. <u>Proceedings of the IEEE, special issue on Multimedia Signal Processing, 86</u>(5), 853-869.

Shaw, R.E., Flascher, O.M., & Kadar, E.E. (1995). Dimensionless Invariants for intentional systems: Measuring the fit of vehicular activities to environmental layout. In J. Flach, P. Hancock, J. Caird, and K. Vicente (Eds.), <u>Global perspectives on the ecology of human-machine systems</u> (pp 293-345). Hillsdale, NJ: Lawrence-Erlbaum, Associates.

Shimojo, S. & Shams, L. (2001). Sensory modalities are not separate modalities: plasticity and interactions. <u>Current Opinions in Neurobiology, 11</u>, 505-509.

Sheridan, T.B. (1992). Musing of telepresence and virtual presence. <u>Presence: Teleoperators and Virtual Environments, 1</u>(1), 120-125.

Shneiderman, B. (1998). Designing <u>the user interface. Strategies for effective human-computer interaction</u>. 3d ed. Reading, MA: Addison-Wesley.

Spence, C. & Driver, J. (1997). Audiovisual links in exogenous covert spatial orienting. <u>Perception and Psychophysics, 59</u>(1), 1-22.

Srinivasan, M.A., Beauregard, G.L., & Brock, D.L. (1996). The impact of visual information on the haptic perception of stiffness in virtual environments. Proceedings of the ASME Dynamics Systems and Control Division, 58, 555-559.

Stanney, K.M., Mourant, R.R. & Kennedy, R.S. (August, 1998). Human factors issues in virtual environments: A review of the literature. Presence: Teleoperators and Virtual Environments, 7(4), 327-351.

Stappers, P.J. (1999). Critical ratios as behavioral indices of presence. 2nd International Workshop on Presence, 6-7 April 1999.

Stein, B.E., & Meredith, M.A. (1993). The merging of the senses. Cambridge, Massachusetts: The MIT Press.

Stephens, B.R. & Banks, M.S. (1987, August). Contrast discrimination in infants. Journal of Experimental Psychology: Human Perception and Performance, 13(4), 558-565.

Storms, R.L. (2002). Auditory-visual cross-modality interaction and illusions. In K.M. Stanney (E.), Handbook of Virtual Environments: Design Implementation and Application (pp TBD). Mahwah, NJ: Lawrence-Erlbaum, Associates.

Stoffregen, T. A. & Riccio, G. E. (1988). An ecological theory of orientation and the vestibular system. Psychological Review, 95, 3-14.

Stuart, R. (1996). The design of virtual environments. New York, NY: McGraw-Hill.

Surdick, R.T., Davis, E.T., King, R.A., & Hodges, L.F. (1997). The perception of distance in simulated visual displays: A comparison of the effectiveness and accuracy of multiple depth cues across viewing distances. Presence: Teleoperators and Virtual Environments, 6(5),513--531.

Turvey, M.T., Shocklet, K. & Carello, C. (1999). Affordance, proper function, and the physical basis of heaviness. Cognition, 73, B17-B26.

Van Der Steen, F.A.M. (1996). Simulating self-motion. Brain Research Bulletin, 40(5/6), 473-475.

Vicente, K.J. (1999). Cognitive work analysis: toward safe, productive and healthy computer-based work.. Mahwah, NJ: Lawrence Erlbaum Assocaites, Inc.

Vince, J. (1995). Virtual reality systems. Reading, MA: Addison-Wesley Publishing Company.

Wallach, Hans (1976). On perception. New York: Quadrangle/The New York Times Books Co.

Warren, W.H., Jr. (1984). Perceiving affordances: Visual guidance of stair climbing. Journal of Experimental Psychology: Human Perception and Performance, 10(5), 683-703.

Warren, R. & Wertheim, A.H. (Eds) (1990). Perception and control of self-motion. Hillsdale, NJ: Erlbaum.

Warren, W.H., Jr. & Whang, S. (1987). Visual guidance of walking through apertures: Body-scaled information for affordances. <u>Journal of Experimental Psychology: Human Perception and Performance, 13</u>(3), 371-383.

Watson, B.A., Walker, N., Hodges L.F., & M. Reddy (1997). An evaluation of level of detail degradation in head-mounted display peripheries. <u>Presence, 6</u>(6), 630-637.

Weimer, J. (1995). <u>Research techniques in human engineering</u>. Upper Saddle River, New Jersey: Prentice Hall Inc.

Wertheim, A.H. (1994). Motion perception during self-motion: the direct versus inferential controversy revisited. <u>Behavioral and Brain Sciences, 17</u>(2), 293-355.

Wickens, C. D. (1992). <u>Engineering psychology and human performance</u> (2nd edition). New York: Harper Collins Publishers Inc.

Witmer, B. G. & Singer, M. J. (1996). Measuring presence in virtual environments: A presence questionnaire, <u>Presence, 7</u>(3), June 1998.

Yamasaki, H., Kakigi, R., Watanabe, S., & Daisuke, N. (1999). Effects of distraction on pain perception: magneto- and electro-encephalographic studies. <u>Cognitive Brian Research, 8</u>, 73-76.