FOREWORD

This report was prepared by the Maintenance Design Branch, Human Engineering Division, Behavioral Sciences Laboratory, under Project 7184, "Human Performance in Advanced Systems," Task 718407, "Design Criteria for Nuclear Systems Support Equipment," with Mr. William N. Kama as Task Scientist. This study was initiated in June 1963 and completed in July 1963.

ABSTRACT

The effect of three viewing conditions—direct, 2D television, and 3D television—upon performance of a simple remote handling task was investigated. Fifteen subjects used a CRL Model 8 master-slave manipulator to perform a shortened and revised version of the Placing Subtest of the Minnesota Rate of Manipulation Test. All subjects performed the task under each of the viewing conditions employed. Results of this study indicated that: (1) subject performance under the direct viewing condition was significantly faster than that obtained under either of the video conditions, and (2) no significant differences were noted between the two video conditions even though performance times under the 2D condition were initially longer than those obtained under the 3D condition.

PUBLICATION REVIEW

This technical documentary report is approved.

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REMOTE VIEWING: A COMPARISON OF DIRECT VIEWING, 2D AND 3D TELEVISION

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INTRODUCTION

Using remote manipulators to perform recovery operations, to do underwater salvage, and possibly to perform space maintenance and repair, gives rise to many complex problems. One such problem is that of providing adequate visual access to the task and to the immediate surrounding area.

Currently, there are three basic viewing techniques used in remote handling situations (ref 2). These are: (1) direct viewing of the task through transparent shielding material, (2) techniques which depend upon a labyrinthian effect for shielding, such as a periscope, and (3) television (video).

This study was designed to investigate subject performance on a simple remote handling task in which either a 2D or 3D closed-circuit television system or direct observation through a window served as the means of attaining visual access to the task. Of particular interest was the problem of determining whether subject performance would differ significantly between the 2D and 3D video conditions.

METHOD

Apparatus

Three main pieces of equipment were used in this study: (a) a master-slave remote manipulator, (b) a closed-circuit television system, and (c) an Armed Forces Vision Tester.

The Manipulator

The manipulator used in this study was a Central Research Laboratories Model 8 master-slave manipulator (figure 1) located in the Aerospace Medical Research Laboratories remote handling facility. Generally speaking, this manipulator can be described as two telescoping tubes connected by an overhead through-tube. One of the telescoping tubes serves as the master or control section while the other serves as the slave or effector portion of the system. The master and the slave portion of the system are mechanically linked and all movements between these two portions are in a 1:1 ratio.

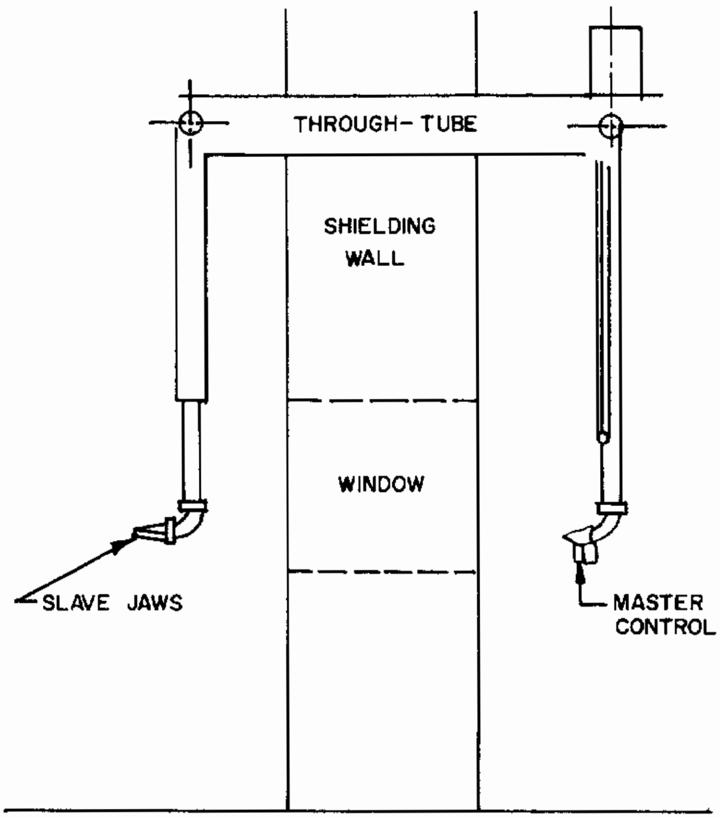

Figure 1. Drawing of the Master-Slave Manipulator

The manipulator was mounted in a hot-cell mockup with the master and slave portion being separated by a shielding wall 91.4 cm (36 inches) thick. A window, 99 cm (39 inches) wide and 122 cm (48 inches) long, provided visual access through the shielding wall.

The Closed-Circuit Television System

The closed-circuit television system used in this study consisted of a Dage Model 70B R vidicon camera, a Wollensak Zoomar lens, and a Dage 602-C 35.5 cm (14-inch) television monitor. Also included in the system was a Stereotronics Corporation 3D kit. This kit consisted of a stereocaptor containing adjustable prisms, a stereoviewing hood, stereoglasses, and a stereoscreen.

In order to change from the conventional 2D system to the 3D system, two minor modifications were necessary. First, the housing of the Zoomar lens was altered so that the stereocaptor could be attached to it. Second, the clear screen on the television monitor was removed and replaced with the stereoscreen. Provisions for attaching the stereoviewing hood to the front of the monitor were also made. A general schematic of the 3D video system is shown in figure 2.

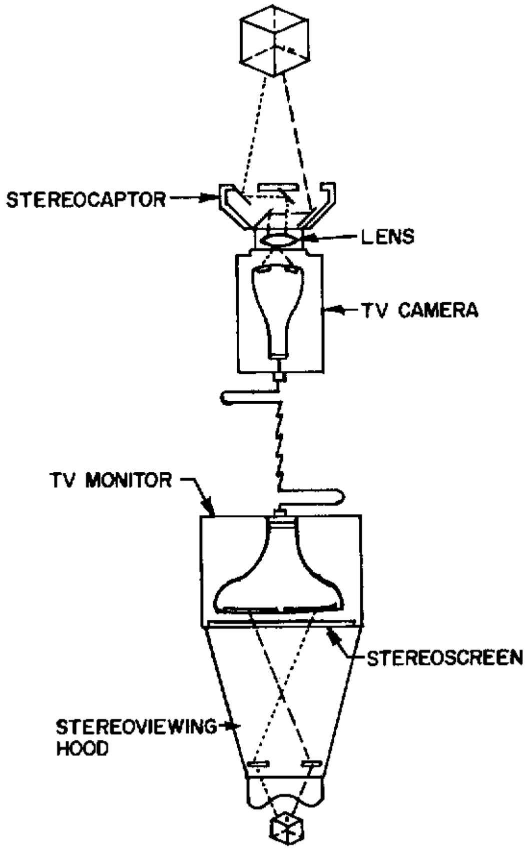

Figure 2

Schematic of the 3D Television System

Adapting the basic 2D system to a 3D system resulted in a 3D video display with one-half the resolution of the 600 lines per inch 2D system. Although this disparity in resolving power was recognized as undesirable, equipment limitations precluded timely correction of this factor. Consequently, in the following discussion the reader should bear in mind that the 2D and 3D systems were not equated in terms of their resolving power.

A cardboard viewing hood, similar in dimensions to the stereoviewing hood, was fabricated and used by the subjects during the 2D video and the direct-viewing conditions. This was done to control viewing angle, head position, sitting height, and to keep the relationship between the master portion of the manipulator and the subject fairly constant for all viewing conditions.

A Bausch and Lomb Armed Forces Vision Tester was used to measure the far acuity and acuity in depth of each subject.

Subjects

Fifteen subjects served for this experiment. Their ages ranged from 19 to 27 years with a mean age of 21.5 years. All subjects were right handed and had either normal or corrected vision of 20/20. The mean depth perception score for all subjects was 8.1 out of a possible maximum score of 12.

PROCEDURE

Upon his arrival at the remote handling facility, the subject was given the far acuity and depth perception tests. Following the administration of these visual tests, he was then taken into the test area and given a short briefing on the manipulator, its mechanics, and the manner in which to operate it. The subject was then allowed to work with the manipulator to better understand its operation. During this period, the subject handled several small blocks, placing them one atop the other. This familiarization period lasted for approximately 5 minutes.

At the completion of the familiarization period, the subject was informed about the purpose of the study, the viewing conditions to be employed, the task to be accomplished, and the procedure to be followed in accomplishing the task. Following this, the television monitor or the cardboard viewing hood (depending on the order in which the subject would be exposed to each of the viewing conditions) was positioned to permit convenient task viewing. The order of presentation of each of the viewing conditions to the subjects was counterbalanced in the following manner:

	Subjects														
Conditions	A	B	C	D	E	F	G	H	I	K	L	M	N	P	R
Direct	3	1	2	1	2	3	1	2	2	3	3	3	2	1	1
2D	2	3	1	2	1	1	3	3	1	2	2	1	3	2	3
3D	1	2	3	3	3	2	2	1	3	1	1	2	1	3	2

The task used in this study was a shortened and modified version of the Placing Subtest of the Minnesota Rate of Manipulation Test (figure 3). The formboard was mounted on a table approximately 114 cm (45 inches) in height in the hot cell directly in front of the observation window. The formboard was mounted at an angle of approximately 120° to the surface of the table.

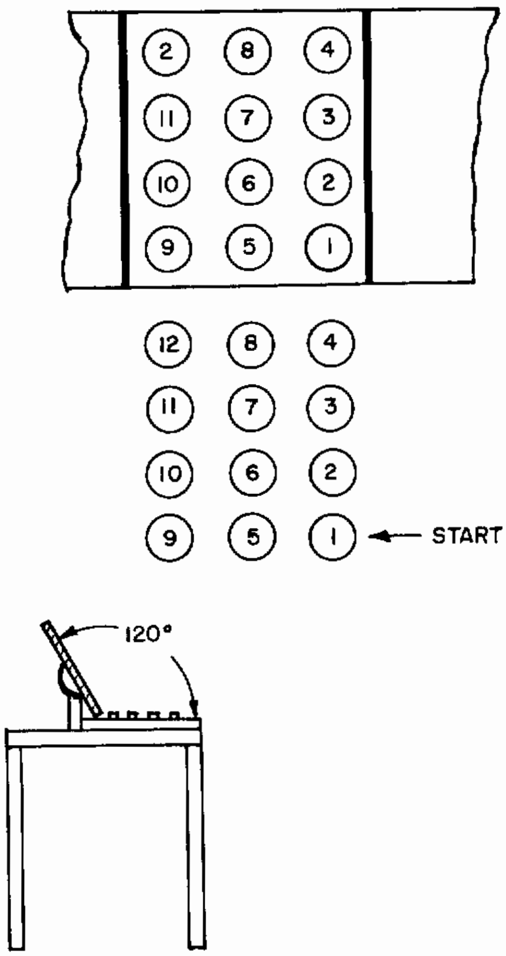

Figure 3. Arrangement of the Modified Minnesota Rate of Manipulation Task as Used in This Study

The pegs were placed at the base of the formboard in three rows of four pegs each. Each row of pegs was directly in line with the corresponding row of holes in the formboard.

The subject was required to place all 12 pegs into the holes in the formboard. He began each trial by picking up the peg that was nearest him in the right hand row, placing it in the bottom hole of the right hand row in the formboard. He then picked up the second peg in the right hand row and placed it in the formboard. He continued to do this until he had placed all 12 pegs into the formboard.

The subject's performance time was recorded for each of the three rows as well as for the total time that it took to complete all three rows. The experimenter used a hand-held stop watch to measure subject performance. The watch was started when the subject grasped the first peg and was stopped when the last peg had been positioned and released. Each subject received a practice trial before doing all three rows under each of the viewing conditions. Although subjects were not told, this practice trial was also timed.

All subjects performed the practice trial and the required task under each of the three viewing conditions employed and thus served as their own control.

RESULTS

The data obtained in this study were analyzed by means of the t-test for related samples. The t-test was performed to determine whether there was a significant difference between subject performance under each of the viewing conditions employed in this study, especially with respect to the video conditions, i e, 2D versus 3D. As expected, there was a significant difference between performance times obtained under the direct viewing condition when compared with times obtained under either of the video conditions (table 1). Table 1 also shows that there was no significant differences between subject performance when the two video conditions were compared.

TABLE 1

t-TESTS OF CRITERION SCORES BETWEEN EACH OF THE VIEWING CONDITIONS FOR EACH TRIAL

	Trials				
Comparisons	Practice	1	2	3	Total
Direct vs 2D	4.70*	2.50*	5.19*	5.85*	3.75*
Direct vs 3D	4.00*	3.55*	3.70*	3.03*	3.74*
2D vs 3D	1.74	0.53	0.24	0.08	0.22

*Significant to .05 level

The data are shown graphically in figure 4. Taken from table 2, the curves show that performance under the direct viewing condition was considerably superior to that which was obtained under either of the video conditions. Further inspection of the curves also indicates that there was very little difference between the two video conditions although performance on the 2D video condition was initially poorer than performance under the 3D condition. The curves for the video condition also show that performance times improved as a function of trials, the 2D condition showing a somewhat better improvement in performance than the 3D condition.

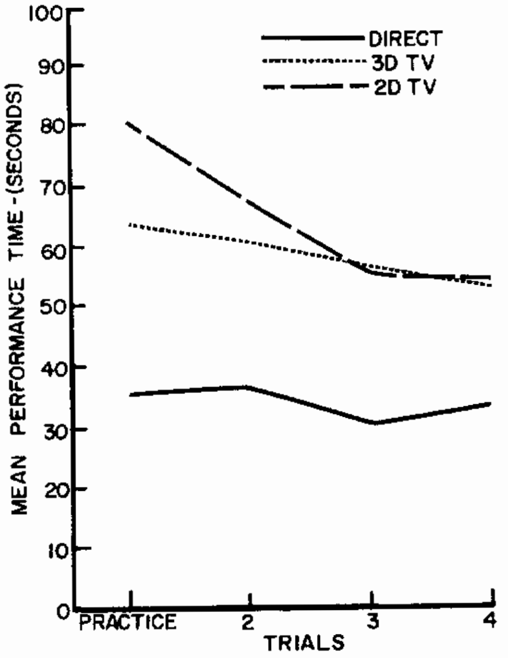

Figure 4

Mean Performance Time as a Function of Trials

TABLE 2

MEAN PERFORMANCE TIMES
AND STANDARD DEVIATIONS (SECONDS)

	Trials									
	Practice		1		2		3		Total	
Viewing Condition	Means	SD	Means	SD	Means	SD	Means	SD	Means	SD
Direct	35.05	13.85	36.19	12.26	30.76	11.62	33.76	13.45	100.71	34.63
3D TV	63.20	41.69	60.73	52.59	56.13	23.99	52.83	16.13	169.69	83.63
2D TV	80.90	28.28	67.53	36.83	55.29	33.27	53.41	32.98	176.23	98.30

DISCUSSION

Analysis of the data obtained in this study indicated that subject performance times for the direct viewing condition were highly superior to those obtained under the video conditions (figure 4). However, performance under this condition showed relatively little improvement as a function of trials.

Further analysis of the data indicated that there existed very little difference between performance times obtained under the 2D video and the 3D video conditions, despite the fact that the 2D video condition initially yielded the poorest performance. In fact, as shown in figure 4, performance times under the 2D condition swiftly equaled or surpassed performance times obtained under the 3D condition as the subjects became better practiced.

The fact that there was no apparent difference in performance under the two video conditions is an interesting, but not an unusual finding. Tollefsbol (ref 1) found that performance of a task under 3D television viewing required as much or more time than was required when using the naked eye or 2D television.

Several reasons can be offered to explain why no differences in performance between the two video conditions occurred.

(1) Loss of Resolution. The closed-circuit television system employed in this study normally has a 600 television line resolution. However, when the system was changed to the 3D system, the resolving power was essentially cut in half. Thus, in effect, the picture for the 3D video condition did not have the sharpness and clarity as that for the 2D video condition. Many of the subjects commented that the 3D video condition offered more depth cues, but the quality of the picture was not as good as that for 2D.

(2) Proprioceptive Cues. The master-slave manipulator used in this study permits a one-to-one correspondence between the relative position of the control arm and effector arm. Accordingly, direct, valid proprioceptive cues were available to the subjects, and this information, being constant over all experimental conditions, may have reduced somewhat the reliance on visual depth cues.

(3) Monocular Depth Cues. The subjects under the 2D video condition probably were able to utilize monocular depth cues—contrast, shadows, interposition, etc—quite successfully and with very little practice. If this is so it would explain the relatively quick improvement in performance times for the 2D condition.

CONCLUSIONS

Major findings of this study were:

1. Subject performance under the direct viewing condition was significantly faster than that obtained under either of the video conditions.

2. No significant differences were noted between performance under the 3D and 2D video conditions even though performance times under the 2D condition were initially longer.

Further investigations should be carried out in this area, using a 3D system that has a higher resolving power than that which was employed in this study. The potential gains that might have been achieved by using a 3D system were possibly masked by the relatively poor resolution of the 3D video display used in this study.

LIST OF REFERENCES

1. Tollefsbol, O.E., Evaluation of Stereo-Television as an Aid to Remote Handling, General Electric Co., Cincinnati, Ohio, July 1954.

2. A Manual of Remote Viewing, Remote Control Engineering Division, Argonne National Laboratory, Lemont, Illinois, August 1952.