VIRTUAL ENVIRONMENTS FOR EXPOSURE THERAPY

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Key Words

Virtual Environment, Acrophobia, Presence, Behavior Therapy

Abstract

We have conducted a controlled study on the use of virtual reality for the treatment of acrophobia--the fear of heights. Subjects experienced a range of physical anxiety symptoms consistent with the apparent threat they encountered from virtual height situations. Pre and post-testing data indicate that a person's perceptions of physical-world situations and behavior in the physical world may be modified based on his experiences within a virtual world. Results of this study provide initial support for the application of virtual reality in psychology/psychopathology and the treatment of psychological disorders.

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INTRODUCTION

Immersion in a virtual environment is a distinctive feature that characterizes virtual reality (VR) as something different from interactive computer graphics or multimedia. The sense of presence in a virtual world elicited by immersive VR technology indicates that there may exist applications of VR that are fundamentally different in nature than those applications that are commonly associated with graphics and multimedia systems. Since the spring of 1993 we have been investigating the possibility of using virtual environments for conducting exposure therapy of individuals with psychological disorders. In this paper we describe the results of a pilot study that used Virtual Reality Graded Exposure to treat acrophobia--the fear of heights. In particular, two issues will be addressed: the extent to which we were able to make subjects "feel" that they were actually present in height situations, and the efficacy of the treatment conducted using virtual height situations.

BACKGROUND

Acrophobia and Graded Exposure

Acrophobia, a simple phobia, is characterized by marked anxiety upon exposure to heights, avoidance of heights, and interference in functioning as a result of the fear (American Psychiatric Association, 1987). Behavioral therapy of acrophobia has included exposing the subject to anxiety producing stimuli while allowing the anxiety to attenuate. These stimuli are generated through a variety of modalities including imaginal (subject generates stimulus via imagination) and *in vivo* (subject is exposed to natural height situations). Systematic desensitization, a form of imaginal exposure in which relaxation is combined with exposure, has long been found to be effective with simple phobics (Marks & Gelder, 1965). Graded exposure is similar to systematic desensitization except that relaxation training is not involved and treatment is carried out in a real-life context (Kaplan and Sadock, 1991). *In vivo* graded exposure is a common and effective treatment for acrophobia and has been shown to be superior to systematic desensitization (Crowe, et al., 1972).

Based on an initial subjective evaluation of what types of height situations cause anxiety in a patient, a therapist using an *in vivo* graded exposure approach to treating acrophobia would arrange therapy sessions in which the patient goes through a process of exposure and adjustment to those situations (habituation). Patients begin with less threatening situations first and gradually work their way up a hierarchy of more anxiety producing situations. For example, if the patient is afraid of heights, therapy sessions might begin by looking through a third floor window with the therapist present. In subsequent sessions the patient might move up to a window on the tenth floor. Other common locations for *in vivo* therapy could be outside stairways, balconies, bridges, and elevators.

Other Work in This Area

Although the past two years have seen increasing interest in applications of virtual reality to psychology/psychopathology, there have been few controlled studies to document its effectiveness. A news report of the existence of a study similar to ours, conducted at Kaiser-Permanente, has been reported in CyberEdge Journal (Lamson, 1994), although analytic results were not presented. In Japan, VR was used to simulate the sand play projective techniques with autistic children (Kijima et. al., 1994). Again, no clinical data were presented, but the authors contended that the VR sand play was useful. A case study of a single acrophobic subject who was treated with virtual reality graded exposure is scheduled to appear in *Behavior Therapy* (Rothbaum, et al., 1994).

Building Environments for Therapy

Based on the types of height situations used for *in vivo* stimuli, we designed a number of virtual height situations. Available graphics workstations for this project were a number of Silicon Graphics machines including a Reality Engine, several Indigos, and three GTX class machines. We defined real-time response as at least ten frames per second. With a ten-frame/second rule as our bottom line we then experimented with the amount of detail we could put into the image. It soon became apparent that we would have to choose between stereoscopic images with a relatively low degree of detail and monoscopic (both eyes see the same image) images with more realistic details provided by texture mapping. Our SGI Reality Engine provided real-time texture mapping but did not support stereo for head-mounted displays. We could provide stereo by running two machines in parallel but none of our other machines were as fast as the Reality Engine nor did they support hardware texture mapping. Additional considerations were the horizontal resolution of our head-mounted display (HMD) and the nature of the environments we wished to generate. The nature of the scenes that we generated was such that most of the important details that implied that the user was in a height situation were located at least several meters away. The relative depth levels defined by discrete pixel widths in horizontal parallax for our HMD (a Virtual Research Flight Helmet with through the optics pixel width of 0.5 cm.)

only allowed five displayable depth locations between three meters and infinity. Based on these considerations we decided to render textured monoscopic images for the acrophobia treatment sessions.

Three environments were created for use in the therapy sessions: an elevator, a series of balconies, and a series of bridges. The three environments are shown in figures 1-4. Modeling was done using Wavefront software (Wavefront, 1989). The Simple Virtual Environment (SVE) software library (Verlinden, et al., 1993) was used to create virtual environments from the models.

The elevator was modeled as an open elevator (no walls or ceiling) located on the inside of a 49 story hotel (figure 1). A guard rail was located about waist high to the occupant. To provide a greater sense of actually being in the elevator we built a wooden platform with guard rails that the subjects stood in to ride the virtual elevator (figure 5). The rail and elevator platform in the real world corresponded in size and position to the rail and platform the occupant saw in the virtual world. Located on the virtual rail were icons to indicate that the occupant wanted to go up, down or stop. We also provided the rider with a tracker for their right hand. A virtual right hand followed the movements of the users' right hand so that it could be used to operate the controls of the elevator. The occupant had tactile feedback in that everything that appeared within reach from the elevator (the rail and floor) could actually be felt or grasped.

The second model consisted of outside balconies attached to a tall building (figure 2). Four balconies were created at different heights: ground level, second floor (six meters), tenth floor (thirty meters), and twentieth floor (sixty meters). As with the elevator we used a wooden platform with guard rails that corresponded in position to the virtual rails on the balcony.

The third model was a canyon with bridges of different heights spanning the canyon from one side to the other. A river ran through the bottom of the canyon. The bridges varied not only in height but also in apparent steadiness. The lowest two bridges (seven and fifty meters) appeared safe and solid (figure 3). The highest bridge (eighty meters, dubbed the Indiana Jones Bridge by one of the subjects), was a rope bridge with widely spaced wooden slats as the flooring (figure 4).

EXPERIMENTAL METHOD

Measures

The *Screening Questionnaire* was constructed for use in this study and assessed inclusion and exclusion criteria. DSM-III-R criteria (American Psychiatric Association, 1987) for simple phobia (i.e., fear of heights, avoidance of heights, belief that the fear is excessive, interference from fear), desire for treatment, desire to participate in a treatment study, presence of panic attacks, history of panic attacks, and presence of claustrophobia were assessed.

The *Acrophobia Questionnaire* (Cohen, 1977) described twenty height situations with rating scales for anxiety (0-6) and avoidance (0-3). The AQ yields a total score ranging from 0-180 and anxiety (0-120) and avoidance (0-60) sub scale scores. Adequate consistency and test-retest reliability have been previously demonstrated for this test, and it has been shown to discriminate between phobic and nonphobic subjects (Cohen, 1977). It has also been responsive to treatment and group effects in several studies (Cohen, 1977; Menzies & Clark, 1993; Pendelton & Higgins, 1983) and was more sensitive to treatment outcome than behavioral tests (Cohen, 1977).

The *Attitude Toward Heights Questionnaire* contained six items assessing attitudes toward heights and was adapted from Abelson and Curtis (1989). These include the following dimensions rated on a 0-10 semantic differential scale: good-bad, awful-nice, pleasant-unpleasant, safe-dangerous, threatening-unthreatening, and harmful-harmless.

The *Fear Questionnaire* was constructed for use in this study. One item was included from the Marks and Mathews (1989) Fear Questionnaire assessing the degree of distress related to acrophobia. The three situations to be used for VR Graded Exposure - glass elevators, outdoor balconies, and bridges - were rank ordered and rated for the amount of discomfort they produced.

Subjective Units of Discomfort (SUDs) were rated approximately every five minutes during exposure on a 0 (no discomfort) to 100 (panic-level anxiety) scale.

Subjects and Procedure

478 students were initially screened in large introductory psychology and computer science classes at two universities in Atlanta via the screening questionnaire. 46 were identified as possible acrophobes; 41 were contacted by phone; 31 were offered entry into the study; 20 were entered, and 17 completed the study. Of those entered, twelve were male, 18 were Caucasian, and the average age was 20 (SD=4.2). Students with concomitant panic disorder, agoraphobia, or claustrophobia were excluded as wearing the HMD might cause them distress.

Subjects (Ss) were randomly assigned to either a treatment (VRGE) group or a wait-list control (WL) group. The pre-treatment assessment (PRE) was conducted in a group format in separate sessions for the treatment and the wait-list groups. At that time, the study was explained, informed consent was obtained, and Ss completed all self-report scales. Wait-list subjects were assessed at PRE, received no treatment, and were assessed again after seven weeks. The first treatment session for the VRGE group was conducted immediately following the assessment, in which Ss were familiarized with the VR equipment. They were allowed to take turns wearing the helmet and were encouraged to interact in VR by looking around a virtual room and "pressing" a button to turn the lights on and off in the room. Treatment was delivered in weekly individual sessions. The post-treatment assessment (POST) consisted of the same battery of questionnaires administered at PRE and was conducted eight weeks following PRE in a group format. Treatment and assessments were provided free of charge.

Following the initial group session, individual virtual reality graded exposure for the treatment (VRGE) group was conducted in seven weekly 35-45-minute sessions by an advanced clinical psychology graduate student. Three Ss habituated completely prior to the eighth session and were terminated early. Height situations were presented in the order determined by each subject's self-rated hierarchy completed at PRE. All sessions were video recorded and were reviewed by a licensed psychologist in supervision.

Ss were encouraged to spend as much time in each situation as needed for their anxiety to decrease and were allowed to progress at their own pace. The therapist simultaneously viewed on a video monitor all the virtual environments (VEs) in which Ss were interacting and therefore was able to comment appropriately.

RESULTS

Presence

Discussions of emotional processing theory as applied to anxiety disorders (Foa and Kozak, 1986; Foa, Steketee and Rothbaum, 1989) purport that fear memories can be construed as structures that contain information regarding stimuli, responses, and meaning. Therapy is aimed at facilitating emotional processing. For this to occur, it has been proposed that the fear structure must be activated and modified. For virtual environments to be effective, they must activate the fear structure and elicit the fearful responses. Evoking a sense of presence in a virtual height situation is therefore essential to conducting exposure therapy.

As a measure of the degree to which subjects felt as if they were present in a physical height situation, SUDs ratings were taken approximately every five minutes during exposure. In exposure therapy using physical height situations the pattern is for subjects' anxiety to increase as they are exposed to more threatening situations, then for habituation to occur (anxiety decreases) as they spend time in the situation. Occurrence of this same pattern for virtual height situations would present evidence that the subjects were experiencing the same reactions and emotions as the experience of a similar physical-world height situation. Mean SUDs for each of the seven exposure sessions are presented in Figure 6. As can be seen, the average SUDs in each session decreased steadily across sessions, indicating habituation. Figure 7 illustrates how SUDS ratings varied with time and bridge height during the first therapy session for the eight subjects who rated bridges as the least scary height situation. Although the absolute SUDs range varied for each subject, the pattern of decreasing SUDs over time and increasing SUDs with higher situations was clearly present. Most Ss appeared to become immersed in the virtual environments. Very often Ss held on to the railings, letting go as they became more comfortable, then grasping hold again as they progressed up the hierarchy. Some sample comments:

S #7:
"I'm feeling a little weak in the knees. My chest is getting tight. My palms are sweaty." (session 2)
"A lot easier than last week. Last week I was terrified." (session 4)
"This is the first time I can look down and not get that weak-in-the-knees feeling." (session 6).
"I went up the glass elevator (outside building) at the Peachtree Plaza...72 floors. I was anxious, but not as much as I used to be. It was much better. No weak-in-the knees feeling." (session 7).

S#1:
"As long as I keep looking at it, it gets better than it was before." (session 1)
"If I don't see the rail, I feel like I'm going to fall." (session 5)

S #16:
"Feel like I'm on the edge ... don't like it." (session 4)
"Feel weak in the knees...wanting to hold on for dear life." (session 5)
"Feel more secure as I walk around. Not so weak in the knees. More sure of it." (session 7)

In addition to SUDs ratings, we also recorded the number and type of physical symptoms of anxiety that were described by subjects during exposure. Physical symptoms of anxiety described by the subjects while in virtual height situations included sweating, abdominal discomfort usually described as "butterflies", loss of balance or light-headedness, heart palpitations, pacing, tremulous or shaking, feeling "nervous" or "scared", weakness in the knees, tightness in the chest, and feeling "tense" (see table 1). In addition to these classic anxiety symptoms, some subjects also reported feeling physical motion sensations such as impact in their knees when the elevator stopped going down. Four subjects also reported nausea and one subject actually vomited during her first virtual height experience. Nausea did not correlate to the height situations experienced as did the other symptoms and seemed to be related to simulator sickness rather than to the height situations experienced. Simulator sickness arises from discrepancies between what the body is perceiving visually and kinetically and feels similar to motion sickness (Hettinger and Riccio, 1992; Pausch, et al., 1992). After we became aware of this, subject sessions were reduced from fifty minutes to 30-40 minutes and Ss were encouraged to stop and rest at the first signs of nausea. With one exception (subject 005), every subject described experiencing from three to eight physical symptoms of anxiety (mean = 5.1 s.d. = 2.4). Subject 005 remarked several times that he had very poor eyesight. His poor eyesight, in conjunction with the limited resolution of our head-mounted display, seemed to limit his experience of physical symptoms.

A third measure of presence was the degree to which subjects' fear and anxiety were reduced by the therapy. This measure is discussed in the next section.

Therapeutic Effect

No pre-treatment differences between PRE and POST groups were detected on any measure or demographic variable. The results of the PRE to POST assessments and the Chi-square analyses on all measures for both groups are presented in Table 2. As can be seen, anxiety, avoidance, distress, and all attitudes towards heights decreased significantly from PRE to POST for the VRGE group but not for the WL group. Examination of the individual attitude ratings reveals that the means on all items were below 4.0 at POST for the VRGE group, indicating positive attitudes on the semantic differential scale. In contrast, all attitudes were negative for the WL group. The average anxiety ratings decreased steadily across sessions, indicating habituation. It is important to note that 7 of the 10 VRGE treatment completers exposed themselves to height situations in real life during treatment although they were not specifically instructed to do so. These exposures appeared to be meaningful, including riding 72 floors in a glass elevator mounted outside the Westin Peachtree Hotel and intentionally parking on the top floor of a parking deck close to the edge rather than in the center of the ground floor.

These results are comparable to Cohen's (1977) results using systematic desensitization and are possibly more impressive. Cohen's pre-treatment anxiety and avoidance scores for treatment-seeking height phobics on the AQ were 60.64 and 13.83, respectively, and are comparable to the pre-treatment scores in our study. Cohen's Ss' anxiety and avoidance raw scores decreased by 28.6 and 6.7, respectively, with systematic desensitization whereas the VRGE Ss' scores decreased by 37.3 and 13.3, respectively.

SUMMARY AND IMPLICATIONS

In summary, we have conducted a controlled study of the application of virtual reality to exposure therapy of acrophobia. Theoretically, the present results are remarkable for many reasons. In particular, they attest to the sense of presence experienced by our Ss in virtual height situations. Ss experienced a range of physical anxiety symptoms consistent with the apparent threat they encountered. The degree of anxiety and habituation observed would not have occurred if the Ss did not feel present in height situations. Regarding emotional processing theory, the fear structures were clearly activated as evidence by the Ss' responses during the VR exposures. They were also apparently modified, as evidenced by the decrease in anxiety, avoidance, and negative attitudes towards heights. The results also support the notion that more elements of the fear structure are changed than are directly addressed in therapy. That is, stimuli and responses were directly manipulated via exposure and habituation. But the meaning associated with these elements also changed significantly, although not directly addressed.

The implications of these results are numerous. We have documented evidence for the experience of a sense of presence in an immersive virtual environment. We have also shown that a person's perceptions of physical-world situations and behavior in the physical world may be modified based on his experiences within a virtual world. We have provided initial controlled study support for the application of virtual reality in psychology/psychopathology and the treatment of psychological disorders.

Within the realm of exposure treatment for anxiety, virtual reality graded exposure may have wide applicability. Many stimuli for exposure are difficult to arrange or control, and when exposure is conducted outside of the therapist's office, it becomes more expensive in terms of time and money. Being able to conduct exposures of virtual airplanes for flying phobics or virtual highways for driving phobics, for example, without leaving the therapist's office would make better treatment available to more sufferers. In addition, many patients have difficulty imaging and therefore are not good candidates for imaginal exposure. VR exposure may provide the necessary images that can be programmed specifically for that patient. An additional advantage of VR over physical world exposure is that exposures can be made as extreme as necessary, providing for overcorrection of the fear and avoidance.

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Figure and Table Captions

Figure 1. View from the elevator.

Figure 2. View from a third floor balcony.

Figure 3. Bridges suspended 7 and 50 meters above a river flowing through a canyon.

Figure 4. Rope bridge suspended 80 meters above a river flowing through a canyon.

Figure 5. Participant riding in the virtual elevator.

Figure 6. Mean SUDs across all subjects for each of the seven exposure sessions.

Figure 7. SUDS ratings with respect to time and bridge height during the first therapy session for the eight subjects who rated bridges as the least scary height situation. Horizontal axes indicate time in minutes at which SUDS were taken, vertical axes indicate SUDS ratings. Session for subject 002 was abruptly ended due to nausea.

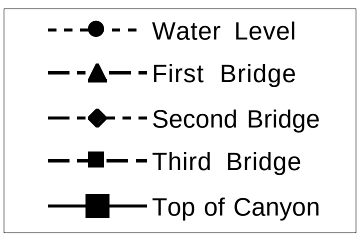


Table 1. Physical symptoms described by subjects during virtual height situations.

Table 2. Means and standard deviations pre- and post-treatment.

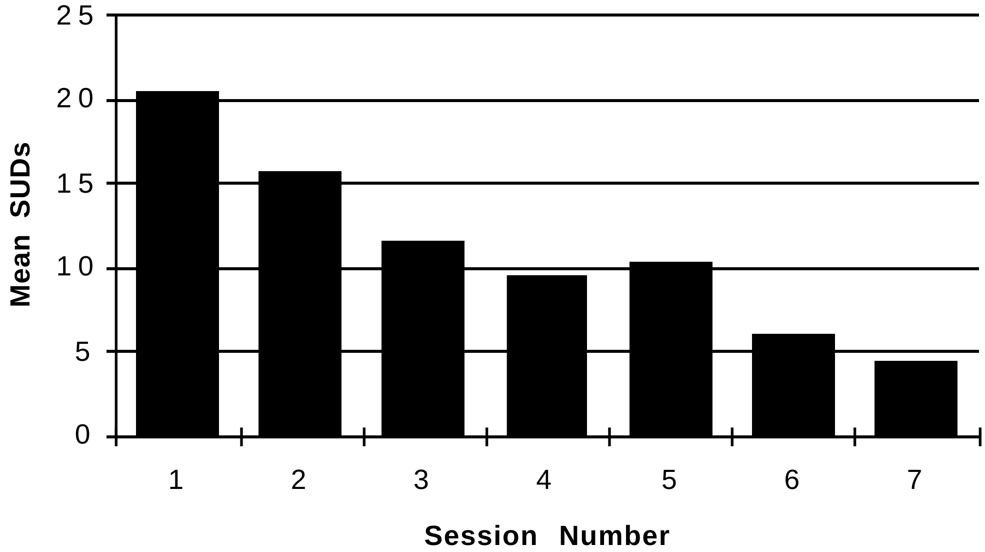


Figure 6. Mean SUDs across all subjects for each of the seven exposure sessions.

TABLE 1. Physical symptoms described by subjects during virtual height situations.

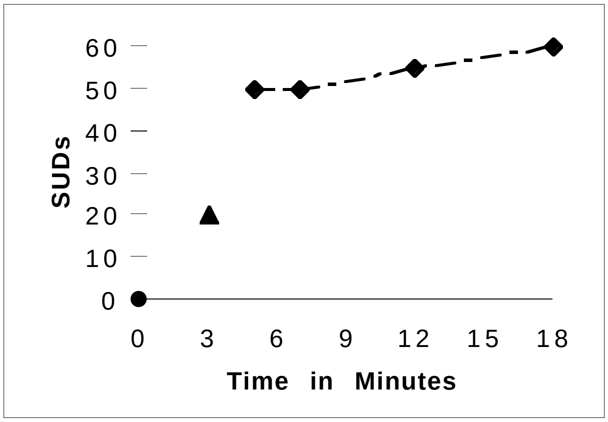
Subject =>	**001**	**002**	**005**	**007**	**011**	**016**	**019**	**022**	**024**	**026**
Sweating	•	•		•	•					
Upset Stomach (Butterflys)	•			•	•		•			
Dizzyness (Light-headedness)	•	•			•	•	•			
Heart Palpatations	•	•				•	•			
Restlessness (Pacing)								•		
Tremors (Shaky)	•				•	•	•			
Nervous/Scared	•	•		•	•	•	•	•	•	
Weakness in Knees	•			•		•				
Nausea Motion Sickness •	•	•	•				•			
Tightness in Chest	•			•	•			•		
Tenseness		•				•		•	•	•
Feel like they are losing balance	•					•	•	•	•	•
Feel physical motion sensations				•				•		•

TABLE 2: Means and Standard Deviations Pre- and Post-Treatment

	VRGE		WAIT-LIST		
	PRE[a] M (SD)	**POST[b] M (SD)**	**PRE[c] M (SD)**	**POST[d] M (SD)**	**X^{2e} (p value)**
ACROPHOBIA QUESTIONNAIRE					
Total	70.9 (34.4)	20.3 (13.2)	70.0 (17.7)	62.9 (19.1)	16.14 (.0001)
Anxiety	54.4 (24.4)	17.1 (11.7)	54.3 (11.4)	46.1 (15.3)	14.79 (.0001)
Avoidance	16.5 (10.8)	3.2 (2.7)	15.8 (7.8)	16.7 (7.7)	14.10 (.0002)
ATTITUDES TOWARD HEIGHTS QUESTIONNAIRE					
Total	41.2 (10.9)	18.0 (10.3)	35.5 (12.6)	39.4 (6.4)	18.14 (.0000)
Bad	6.6 (1.7)	2.9 (1.8)	5.0 (2.1)	5.6 (0.5)	18.91 (.0000)
Awful	6.0 (1.5)	2.9 (1.6)	5.3 (2.3)	6.0 (0.6)	14.69 (.0001)
Unpleasant	5.7 (3.1)	3.5 (1.7)	6.0 (2.4)	7.0 (1.5)	4.43 (.0353)
Dangerous	7.4 (2.5)	3.0 (2.3)	6.5 (2.6)	7.3 (1.6)	14.71 (.0001)
Threat	7.0 (2.0)	3.0 (1.9)	6.6 (2.7)	6.9 (1.9)	11.76 (.0006)
Harmful	6.8 (2.0)	2.7 (1.8)	6.1 (2.0)	6.7 (1.8)	18.31 (.0000)
DISTRESS FROM FEAR					
	4.1 (1.8)	1.9 (1.3)	3.5 (1.3)	3.3 (1.5)	9.33 (.002)

[a]n=12; [b]n=10; [c]n=8; [d]n=7

[e]The effect of VR treatment on the above scores was tested using the change by treatment interaction term from a repeated measures MANCOVA computed with the BMDP 5V computer program (Dixon, Editor, BMDP Statistical Software Manual, Vol. 2, University of California Press, Berkeley) using the REML algorithm and compound symmetry covariants structure.



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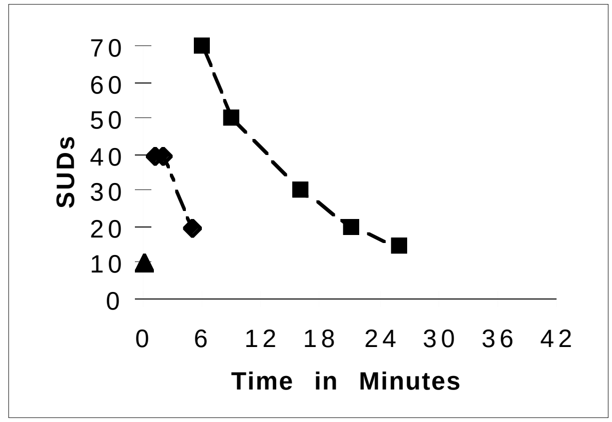

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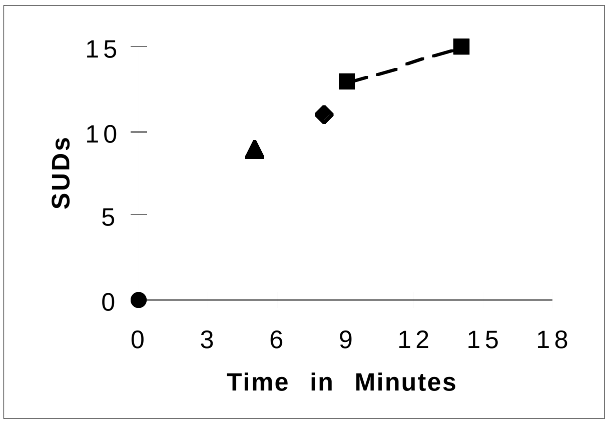

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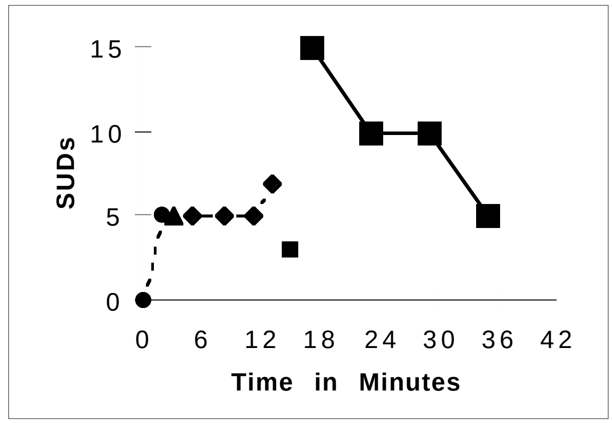

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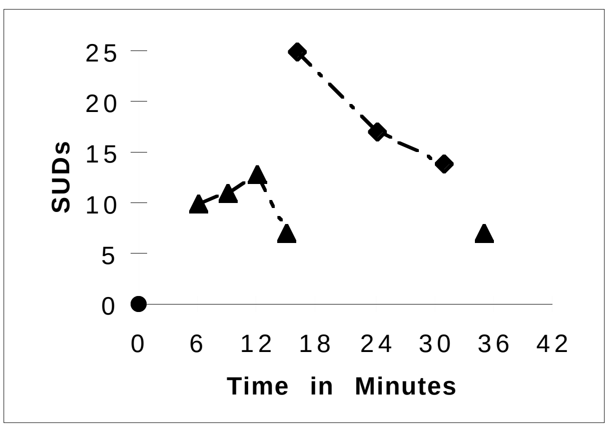

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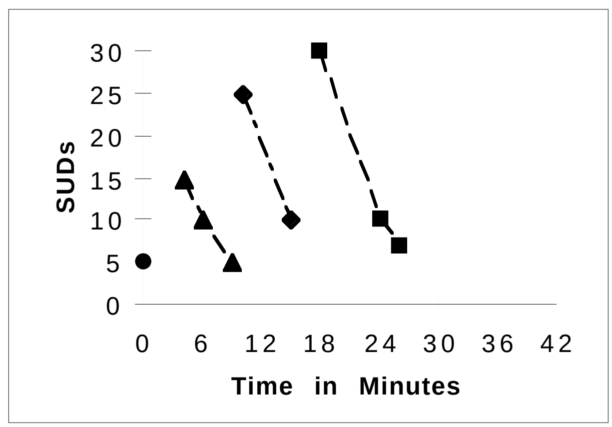

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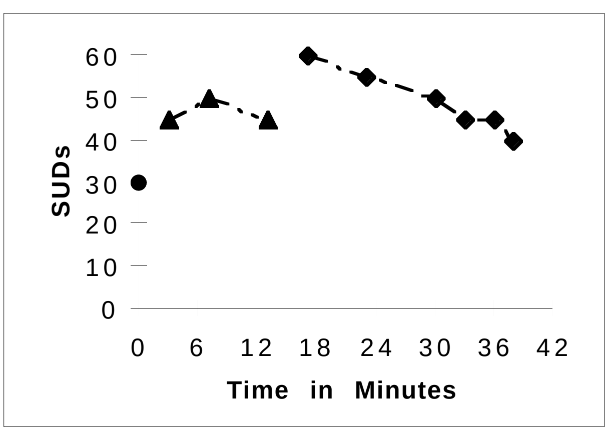

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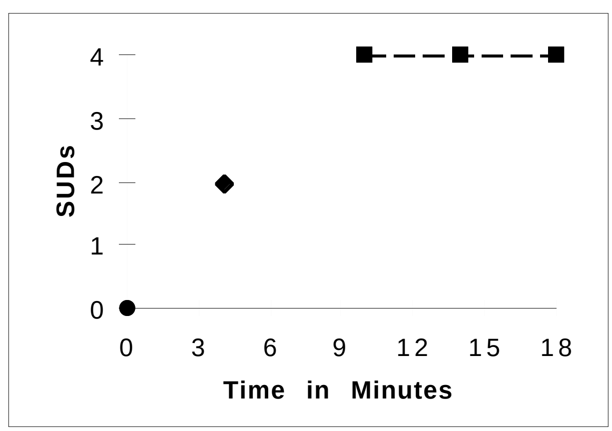

Subject 026

Figure 7