Perspective viewing, Anaglyph stereo or Shutter glass stereo ?

Sabine Volbracht
sabaro@uni-paderborn.de

K. Shahrbabaki*
khatoun.shahrbabaki@sap-ag.de

Gitta Domik
domik@uni-paderborn.de

Gregor Fels
gf@chemie.uni-paderborn.de

Universität- Gesamthochschule Paderborn, Fachbereich 17
Fürstenallee 11, 33102 Paderborn, Germany
* SAP AG, Postfach 1461, 69185 Walldorf, Germany

Abstract

This paper describes a case study that assessed the strenghts and weaknesses of 3D display modes: perspective viewing, anaglyph stereo and shutter glass stereo. We followed the hypothesis that stereo viewing allows a faster and more accurate recognition than the anaglyph and the perspective viewing. For our case study, we used organic molecules. Although these have inherent spatial information we think that results of this experiments are applicable to the visualization of abstract information spaces in VL.

1 Introduction

Visualization experts are mainly concerned with the question of how to map data to meaningful pictures. A meaningful visualization must fit syntax and semantics of these data, support the visualization goals (task), conform to the problem domain, adapt to the user as well as be adequately supported by available computer resources, which determine visualization techniques and display modes [2]. Over the past few years, 3D graphics has received a great deal of attention and is widely acknowledged as a challenge in VL [7], Computer Graphics, Scientific Visualization [5], HCI [6], and many other areas.

One of the interesting issues is *how* effective a particular visualization technique is [7]. Effectiveness of visualization techniques and display modes is yet little understood. General discussion on effectiveness of visualization techniques, including spatial readability, have thus been limited value to system builders [4, 3]. Our study differs in that it reduces the testing environment to one application area (namely chemistry), one visualization technique (the molecule stick model) and three 3D display modes (perspective viewing, anaglyph stereo and shutter glass stereo). We then make observations on the effectiveness of different display modes by measuring accuracy and time during the performance of the tasks by the users. The visualization technique as well as the tasks used in our experiment are taken from Organic Chemistry. Structures are represented as stick models, easily understood by the organic chemists. Stick models are often used to show the structures of the molecule.

The three different 3D display modes (*perspective viewing*, *anaglyph stereo* and *shutter glass stereo*) were implemented as following:

Perspective viewing: The molecules are projected onto a 2D plane using perspective projection and color.

Anaglyph stereo: Two perspective views of the molecules are generated, a right- and a left-eye perspective view with complementary colors (red/green or red/blue).

Shutter glass stereo: Two perspective views of the molecules are generated using the same color scale as in the perspective molecule. Here the right- and left-eye views of the molecules are presented alternatively on the screen with 120 Hz.

2 Experiment

Our experiment involved 81 participants and was based on Eberts [1]. The subjects were students of Chemistry (mean subject: organic / other) or Computer Science and had different experiences with 3D representations. The task were performed interactively on each of the 3D display modes. The interaction was restricted on molecule rotations with the mouse. For each task the subject saw a different molecule. In this way we avoided that subjects remembered the structure of molecules. Three tasks (identifying, comparison and movement) were tested by providing five questions. Identifying and comparison were each tested with a simple and a complex molecule to understand the relationship between complexity and viewing. Additionally another identification task without interaction was considered. The particularity of this is the absence of hidden relevant objects. The six questions were as follows:

Q1.**Identifying (simple molecule)** How many rings are in this molecule?

Q2.**Identifying (complex molecule)** How many rings are in this molecule?

Q3.**Comparison (simple molecule)** Which atom is the first and which is the last on the z-axis?

Q4.**Comparison (complex molecule)** Determine the order of the benzene rings on the z-axis.

Q5.**Movement** Position the benzene ring parallel to the screen plane.

Q6.**Identifying** How many benzene rings are in this molecule?

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3 Results and Discussion

	P	A	S
Q1: E (error rings)	-0.30	-0.04	-0.11
Q1: T	26.75 sec	22.40 sec	25.64 sec
Q2: E(error rings)(variance)	0 (10.46)	-1.96 (7.81)	-1.15 (5.90)
Q2: T	91.84 sec	66.93 sec	67.02 sec
Q3: E (error distances in angstroms)	4.266	1.374	1.167
Q3: T	92.77 sec	70.86 sec	53.08 sec
Q4: E (error distances in angstroms)	4.380	0.780	0.953
Q4: T	137.07 sec	90.37 sec	79.04 sec
Q5: E (error angle in degrees)	11.78	4.65	4.75
Q5: T	78.48 sec	58.32 sec	76.25 sec
Q6: E(error rings)	-0.11	-0.67	-0.59
Q6: T	33.69 sec	45.87 sec	43.31 sec

Tabelle 1: Main effect of display mode for P (perspective), A (anaglyph) and S (shutter glasses) averaged over 27 subjects and three experience levels. 'E' represents the mean response error, 'T' the mean response time.

Table 1 summarizes the main effects of display modes from our experiment. Mean response errors and mean response times were computed separately by a two-way Analysis of Variance (ANOVA). A Newman-Keuls test ($\alpha = 0.05$) was applied for comparing the different mean errors and mean times.

The four first rows of the table (**Q1**, **Q2**) show an interesting result of our experiment. For **Q1** the differences in mean errors and mean times for display modes are not significant, but in **Q2**, where the molecule was more complex (Error: $F(2,72) = 3.43$, $p= 0.03765064$; Time: $F(2,72) = 5.35$, $p = 0.00681$). A Newman-Keuls test indicated, that identifying in shutter and anaglyph mode has been performed more accurate and faster than in perspective mode.

In tasks three and four (**Q3**, **Q4**), where the spatial information was relevant, viewing in perspective mode was considerably worse than stereo modes, as expected. For **Q3** (Error: $F(2,72) = 21.65$, $p < 0.00001$; Time: $F(2,72) = 12.54$, $p = 0.000021$) the main effect of display modes shows that comparison of small objects was better in shutter mode than in the other modes. By comparison of larger objects (**Q4**: Error: $F(2,72) = 18.80$, $p < 0.00001$; Time: $F(2,72) = 14.47$, $p = 0.0000052$), a Newman-Keuls test indicated that the differences of the shutter and the anaglyph mode are not significant.

The analysis of the obtained data from **Q5** (Error: $F(2,72) = 16.09$, $p < 0.00001$; Time: $F(2,72) = 4.78$; $p = 0.01126$) showed an interesting result, namely that positioning errors were smaller in anaglyph and shutter mode than in perspective mode but the position time was only significantly better in anaglyph mode. The difference in mean time of shutter and perspective mode was not significant.

An unexpected result was that perspective viewing makes it easier to count bezene rings as long as the information was not hidden (**Q6**: Error: $F(2,72) = 4.33$, $p = 0.01681865$; Time: $F(2,72) = 4.78$,$p = 0.01126$). An explanation may be, that if the third dimension doesn't provide any necessary information it made the interpretation of the visualization more difficult. We presume that in such a case a redundant visual cue decreases the effectiveness of a visualization. However, perspective viewing is often not reliable, because information might be hidden.

A very interesting outcome was that viewing in the anaglyph mode is similar good as in the shutter mode. Our study also demonstrated that when identifying the number of rings the Chemistry students performed better (main effect of experience: **Q1**: Time: $F(2,72) = 5.35$, $p = 0.00681$; **Q2**: Error: $F(2,72) = 4.55$, $p = 0.01381$). In all other questions we couldn't notice a significant difference between Computer Science and Chemistry students. Thus, expert-novice differences in field chemistry may not be relevant for depth perception in this context. The relationship between complexity and viewing is that by decreasing complexity the differences in accuracy and time between the perspective mode and the two stereo modes also decreases. We suppose a similar visualization technique to stick models, e.g., flow charts or networks would obtain the same results. Due to that, the designers of visual languages could benefit from our results. Finally, our efforts have focused primarily on differences between display modes and how these facilitate the understanding of information.

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