Who’s in Charge Here?: Communicating Across Unequal Computer Platforms

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Statement of Research

Beside the dramatic increase of computer power in the last years, a breach between the PDAs and workstations is expected to be present due to their mobility constraints. This breach creates heterogeneity between the different computer platforms. The popularity of Personal Data Assistants (PDA) devices and the wide use of wireless technologies have made possible the collaboration between heterogeneous computer platforms.

Having persons working collaboratively in a shared environment, one of them is in the field using a Personal Data Assistant (PDA) and his partner using also a PDA or using a powerful workstation in an office, is a work scenario likely to happen. It is important to understand the issues raised by the platform disparities on work communication and its impact on the task performance, so we can build systems that can accommodate such disparities and effectively support the collaboration.

The heterogeneity can be defined not only in terms of speed, bandwidth, and input and output devices capabilities, but also in terms of the disparity in the way the information is visually represented. There is a large pool of possible input devices that can be used in a workstation, from devices like mouse and keyboard, to sophisticate eye trackers and workbenches. In the other hand, PDAs offer a smaller and less efficient set of options due to their mobility constrains. The displays differences are the result of their physical characteristics, such as size, color resolution, aspect ratio, and spatial distribution. In terms of visual representation of the information, the disparities can result from the level-of-detail, dimensionality (3D or 2D) of the representations, degree of abstractions of summarization, and view fragmentation.

In this work, we studied the consequences of introducing two types of disparities: display size and dimensionality of the representation. Also, due to the platforms’ nature, different displays and input devices are used: a traditional mouse for the workstation and stylus for the PDA. We selected a scenario where two persons are working collaboratively in a shared virtual environment where the person using the workstation has a 3D representation and the person using a PDA has a 2D representation (front view and top view) of the problem. Possible applications where this scenario is likely to support are training, equipment maintenance, and medical emergency support. We have chosen to compare the 2D and 3D information representation because the computing capabilities, number of pixels and screen size of the PDA prevent it from rendering an interactive 3D representation with the same features and frame rates. Our research compares collaborations taking place in homogeneous and heterogeneous environments when one person leads the communication. We analyze the performance and conversations taking place looking for changes in the collaboration, so be can have a better understanding of how to support better the collaboration among mixed environments.
1 Detail Description of Subjects

1.1 Questionnaire Data Analysis

Total of 36 subjects (all right-handed males) participated in Slow Tetris Experiment. Every subject had a role in the collaboration part: 18 (50%) were communicators and 18 (50%) were doers. Also, half of the subject population worked on PC – 18 (50%) and the second half used PDA – 18 (50%).

1.1.1. Background

According to the field of study, majority of subject population comes from Computer Science, Electrical and Biomedical Engineering and similar fields – 22 (61.11%). The rest comes from:
- Math, Finance, Statistics and Industrial Systems – 5 (13.89%)
- Economics – 2 (5.56%)
- Philosophy – 1 (2.77%)
- Psychology – 1 (2.78%)
- Biology – 2 (5.56%)
- Languages – 1 (2.77%)
- Political Science – 1 (2.78%)
- History – 1 (2.78%)

21 (58.33%) males were drawn from undergraduate student population, while the rest, 15 (41.67%) was drawn from graduate student population.

All subjects have experience in using computers for many years. The average number is 9.58 years.

The following chart shows the distribution of subjects according to the number of years they have been using computers:
Since we were targeting our experiment to males who are video games fans and have experience in playing video games, most of the subjects – 34 (94.44\%) confirmed their proficiency in the field of playing video games, while only two (5.56\%) subjects expressed no experience at all.

In addition, we were interested in few follow-up questions: for how long they have been playing video games, how often, kind of input devices they have been using, etc.

Majority of the subject population has been playing video games for long period. The average number is 10.9 years. The following chart shows the distribution of subjects according to their experience in playing video games:

In terms of frequency, i.e. how often they play video games during the week, it is surprising that only three subjects (8.33\%) spend over ten hours per week playing video games. Most of the subjects spend less than one hour per week playing video games – 17 (47.22\%), while nine subjects (25\%) spend between one and five hours per week, and five subjects (13.89\%) spend between five and ten hours per week playing video games.
Two subjects (5.56%) didn’t answer this question since they don’t have experience in playing video games at all.

The following chart shows the distribution of subjects according to hours they spend playing video games during the week:

![Video games in hours per week chart]

1.1.2. Input devices

The following chart shows the distribution of subjects according to the input devices they have used:

![Input devices chart]

When asked about the experience with virtual environments: one (2.78%) subject didn’t answer the question; 17 (47.22%) subjects answered that they have no experience
in virtual environments, and 18 (50%) subjects said they do have experience in virtual environments.

When asked about the experience with 3D computer programs: nine (25%) subjects don’t have any experience; 26 (72.22%) subjects have experience with 3D computer games, and one (2.78%) subject didn’t answer the question.

1.1.3. Age

The following chart shows the distribution of subjects according to the groups of age they belong to, where:

1.1.4. The 2D Application

On the scale 1 to 7, 1 being the lowest score and 7 being the highest, each subject was asked to rate 2D application in terms of following:

1. I found the 2D application easy to use:
The average answer was 3.6.
One subject didn’t answer this question.

2. The 2D application sometimes confused me:
The average answer is 5.
One subject didn’t answer the question.

3. It was easy to learn how to manipulate objects in 2D environment:
The average answer is 4.2.
One subject didn’t answer the question.
4. In 2D I found difficult to collaborate with my partner when he was also using a 2D application:
The average answer is 2.8.
13 subjects didn’t answer this question.

5. In 2D I found it difficult to collaborate with my partner when he was using a 3D application:
The average answer is 2.4.
14 subjects didn’t answer the question.

6. I liked using the 2D environment:
The average answer is 3.
Three subjects didn’t answer the question.

Subjects were asked to elaborate their scores in question 6.
According to what they wrote:
Eight subjects expressed positive opinion about the 2D application saying that it was easy enough to figure out rotations to build and considered it a simple and intuitive interface where things are shown in a simple manner; for one of them it was energy consuming while doing 2D, while three of them thought about 2D as fun – it made them think of ways how to solve the task and to imagine blocks in mind. One of them also said that Slow Tetris game reminded him on times when he was in the kindergarten playing puzzles.

One subject was neutral saying that there was nothing special about 2D application.

The rest mostly complained about the 2D application:
22 subjects wrote that 2D application was very confusing, difficult to use and manipulate, complicated to determine and visualize shapes of the objects. Three subjects said that 2D was hard to manipulate at the beginning but they got used to it later.
Two subjects wrote that 2D application required more self-training, more time and engagement than 3D.
One subject complained about the blue border that shows which blocks are active – it was very confusing.
Only one subject said explicitly that the 2D application was frustrating.
Six subjects complained about the views in the 2D application: they said it was pain to switch views in order to rotate a certain way; that the views restricted their moves and made harder to predict how rotations will look like.
Five subjects didn’t elaborate this question.
1.1.5. *The 3D Application*

On the scale 1 to 7, 1 being the lowest score and 7 being the highest, each subject was asked to rate 3D application in terms of following:

**7. I found the 3D application easy to use:**
All subjects answered the question. The average answer is 6.

**8. The 3D display sometimes confused me:**
All subjects answered the question. The average answer is 3.

**9. It was easy to learn how to manipulate objects in the 3D environment:**
All subjects answered the question. The average answer is 6.

**10. In 3D I found it difficult to collaborate with my partner when he was also using a 3D application:**
The average answer is 2.4.
13 subjects didn’t answer this question.

**11. In 3D I found it difficult to collaborate with my partner when he was using a 2D application:**
The average answer is 3.2.
14 subjects didn’t answer this question.

**12. I liked using the 3D environment:**
The average answer is 6.26.
Two subjects didn’t answer this question.

Subjects were asked to elaborate their scores in question 12.
According to what they wrote:
- 21 subjects said that 3D application was clear - they could easily visualize and figure out shapes of the objects; objects were displayed nicely (clear graphic) that enables them to see hidden faces of the blocks and distinguish pieces from the white background; for all of them 3D application was convenient and nice.
- Six subjects said that 3D application was fun and enjoyable, intuitive, closer to reality and challenging.
- Four subjects compared it to the 2D application saying that 3D required less time and engagement to get used to it; they were more used to input device in 3D than to input devices in 2D; for one of them 3D was less challenging, while one said that 3D was harder to manipulate but easier to plan moves.
- Two subjects said that 3D was like a game.
- One complained about the rotations saying that lack of more than just two rotations was initial difficulty.
- Two subjects said that they prefer using 3D since it is better but still not fun.
One of the subjects noticed that the ability to see the back of the wall sometimes would have helped him.

1.1.6. The Roles – Communicator vs. Doer

13. Subjects were asked to state in which environment was easier for them to perform tasks.

Out of 18 communicators, 15 said that the 3D application was easier to use while three didn’t answer the question. Of those 15 who preferred the 3D application, two subjects added notes that they used 3D environment only in a collaboration part, which means that they didn’t understand the question. The question confused them since it is not explicitly stated in the question that this considers both parts of the experiment.

Doers answered as follows: 10 doers said that 3D application was easier to perform tasks; two doers answered that 2D application was easier; six doers didn’t answer the question – most of them wrote that they used only 2D application – which again implies that the question was not clear enough.

14. Communicator – I found it easy to communicate the instructions
   Doer – I found it easy to understand instructions

All subjects answered the question.
Communicators’ average answer is 5.7.
Doers’ average answer is 6.3.

15. Both communicators and doers were asked to answer whether it was easier to give / understand instructions when they were using 2D or when using 3D environment.

Communicators answered as follows: eight communicators selected the 3D application as an easier environment to give instructions; one communicator answered that 2D environment was easier for him when giving instructions (but since he wrote a note that he used only 2D application in the experiment, we may conclude that he didn’t have other options to select for an answer); nine communicators didn’t answer this question – most of them, as in the previous question, wrote notes saying that they were using only 2D or 3D applications so it appears that they didn’t have other options to put as an answer.

Doers answered as follows: nine doers selected the 3D application as the easier one when understanding instructions; three doers said that it was easier for them to understand instructions from the 2D application, though two of them wrote notes that they used only 2D environments during the experiment, which again implies a possibly confusing question; five doers didn’t answer this question.

16. Both communicators and doers were asked to state whether it was easier for them to give / understand instructions when their partners were using 2D or when using 3D application.
Communicators answered as follows: six communicators favored the 3D environment; four subjects favored the 2D environment; for five communicators there was no difference between the environments; three subjects didn’t answer this question.

Doers answered as follows: 12 doers favored the 3D application; three doers favored the 2D application; three doers didn’t answer this question – one of them even wrote a note that he didn’t know what his partner was using during the experiment.

17. Subjects were asked to score the system – if it provided an effective and efficient means to accomplish the Slow Tetris task:
The average answer for this question is 5.7.
Two subjects didn’t answer the question.

18. Furthermore, subjects were asked to write what other information the system should provide in order to enhance collaboration. According to what they wrote:
   - Four subjects said that system worked fine and adequately, and it provided enough information for collaboration.
   - Five subjects complained about the views: they said it would be easier to manipulate both environments if they had more views, or back view in 2D application, or any other way to see the hidden faces of the blocks.
   - One subject suggested that the system should provide zooming option.
   - Five subjects wished if there were possibilities in 2D environment to have views simultaneously displayed on separate regions of the screen.
   - One subject asked for more descriptive labels for each rotation.
   - One subject suggested implementing “undo” feature in both environments.

19. If you were designing the system what would you have done differently?
According to what subjects wrote:
   - 17 subjects concluded that the system should provide more features: some of them specified that there should be more rotation options – two side rotations in 2D; three or even more rotations in 3D (top, front and side); some subjects said they would provide more view options such as back or rear view in 2D, as well as side view in 2D; more views in 3D; one subject didn’t specify what he considered by “more features”; one subject suggested in 2D to put views and the tool pane on the same screen.
   - Six subjects gave comments on the quality of communication saying that: everybody should speak clear enough; system should provide some other ways of communication in addition to telephone; to use better phones or to put partners in the same room or place so they don’t have to use speakerphones.
   - One subject suggested to eliminate 2D application altogether.
   - One subject complained about the input device and suggested to find some other options for 2D input device.
Five subjects didn’t answer this question at all.
Five subjects already wrote their suggestions in the question 18 so they skipped the question 19.
1.1.7. Impressions About Partners

20. My partner seems to be intelligent.
The average answer for the first partner: 6
The average answer for the second partner: 6.11 (One subject didn’t answer the question)

21. My partner seems to be honest.
The average answer for the first partner: 6.22
The average answer for the second partner: 6.24 (Two subjects didn’t answer the question)

22. My partner seems to be fair:
The average answer for the first partner: 6.06 (One subject didn’t answer the question)
The average answer for the second partner: 6.2 (One subject didn’t answer the question)

23. I think I can collaborate well with this partner:
The average answer for the first partner: 6
The average answer for the second partner: 5.91 (One subject didn’t answer the question)

24. My impression is that this partner is rational:
The average answer for the first partner: 6.09 (One partner didn’t answer the question)
The average answer for the second partner: 6.15 (Two subjects didn’t answer the question)

25. My partner was untrustworthy / trustworthy:
The average answer for the first partner: 6.34 (One subject didn’t answer the question)
The average answer for the second partner: 6.35 (Two subjects didn’t answer the question)

26. My partner was weak / powerful:
The average answer for the first partner: 5.47
The average answer for the second partner: 5.49 (One subject didn’t answer the question)

27. My partner was unkind / kind:
The average answer for the first partner: 5.78
The average answer for the second partner: 5.74 (One subject didn’t answer the question)

28. My partner was unfriendly / friendly:
The average answer for the first partner: 6.06 (One subject didn’t answer the question)
The average answer for the second partner: 6.03 (Two subjects didn’t answer the question)

29. My partner was rigid / flexible:
The average answer for the first partner: 5.8 (One subject didn’t answer the question)
The average answer for the second partner: 5.82 (Two subjects didn’t answer the question)
30. My partner seemed to be aggressive:
The average answer for the first partner: 2.77 (One subject didn’t answer the question)
The average answer for the second partner: 3.06 (Two partners didn’t answer the question)

31. My partner was helpful when performing the task:
The average answer for the first partner: 5.97 (One subject didn’t answer the question)
The average answer for the second partner: 5.88 (Two subjects didn’t answer the question)

32. My partner was competitive / cooperative:
The average answer for the first partner: 6.26 (One subject didn’t answer the question)
The average answer for the second partner: 6.15 (Two subjects didn’t answer the question)

33. My partner was cold / warm:
The average answer for the first partner: 5.54 (One subject didn’t answer the question)
The average answer for the second partner: 5.59 (Two subjects didn’t answer the question)

34. My partner was manipulative / sincere:
The average answer for the first partner: 5.8 (One subject didn’t answer the question)
The average answer for the second partner: 5.79 (Two subjects didn’t answer the question)

35. My partner was selfish / unselfish:
The average answer for the first partner: 5.6 (One subject didn’t answer the question)
The average answer for the second partner: 5.59 (Two subjects didn’t answer the question)

1.1.8. General Thoughts

36. The experiment took too long.
The average answer is 3.2.
Two subjects didn’t answer this question.

37. Subjects were asked to provide any other suggestions or comments they had beside those they already wrote in questions 18 and 19.
23 subjects (64%) didn’t give additional comments or suggestions since they already put them in questions 18 and 19.
There is only one subject that didn’t give any comment or suggestion at all, including questions 18 and 19.
The overall impression of two subjects about the experiment was very positive.
Their comments were: It was fun; Thanks!
One subject suggested more verbal explanations before experiment instead of giving written introductions and descriptions.
One subject was obviously annoyed by the time the experiment took since he wrote that we should shorten the time by making sure that connections work.

There are six (14%) subjects who criticized questions about their partners in the questionnaire. Their comments were: partner was irrelevant; can’t rate partners with stuff asked in this questionnaire; questions about partners were not well established; skip 80% of the questions about the partners; not able to judge person with such an experiment; neutral in feelings about my partner.

In questions 38 – 45, subjects were asked to answer indicating how they felt personally about each statement, using score 1 – 7, with 1 being “Strongly Disagree” and 7 being “Strongly Agree”:

38. In dealing with strangers one is better off being cautious until you have evidence that the stranger is trustworthy:
   The average answer is 5.3.
   All subjects answered the question.

39. In these competitive times, one has to be alert or someone is likely to take advantage of you:
   The average answer is 4.8.
   All subjects answered the question.

40. Society will fall apart if police power that counters criminal activities weakens:
   The average answer is 4.6.
   All subject answered the question.

41. One should not trust others until one knows them well:
   The average answer is 4.8.
   All subjects answered the question.

42. Most people tell a lie when they can benefit from doing so:
   The average answer is 4.6.
   All subjects answered the question.

43. When someone says something complimentary about you it’s because they want to get something from you:
   The average answer is 3.4.
   All subjects answered the question.

44. People will take advantage of you if you cooperate with them:
   The average answer is 3.2.
   All subjects answered the question.

45. Given the opportunity people are dishonest:
   The average answer is 3.33.
   All subjects answer the question.
1.2 Performance Information

There were 41 male subjects for the practice period, one of them was not able to complete the training in the 2D interface between the 2 hours limit. Table 1 shows the average time in the 2D and 3D environments that it took to the subjects to fit the blocklets.

Table 1 shows the performance differences we found in the practice period. The average time for fitting a blocklet when using the 3D interface is half the time needed when using the 2D interface.

Figure 1 shows the average time for all subjects to fit a blocklet in the practice period in both, 3D and 2D tasks representations. Since subject 37 did not finish the training, the average time is missing and appears in the graphic as zero. Figure 2 shown the performance differences in both environments. One subject exhibited the same performance in both environments, and five of them had differences equal or less than 10 seconds in favor of the 3D representation. Two subjects shown a better performance in the 2D than in the 3D, 22 and 28 seconds, while three had a notorious decrease in their performance when changed from the 3D environment to the

<table>
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<th>Environment</th>
<th>Mean</th>
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<td>2D</td>
<td>86</td>
<td>44</td>
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Table 1 shows the performance differences we found in the practice period. The average time for fitting a blocklet when using the 3D interface is half the time needed when using the 2D interface.

Figure 1: Average time for fitting a blocklet in the practice period for all subjects.
2D: 133, 147 and 182 seconds of difference.

3D and 2D average fitting time on practice

![Graph showing 3D and 2D average fitting time on practice](image)

Figure 2: Shown is...

2 Detail Experiment Description

2.1 Design Phase of the Experiment

Slow Tetris Experiment is a continuation study of the general research that deals with collaboration using heterogeneous environments. Experiment is comprised of tasks that simulate a real-world problem of an office-bound help-desk person assisting a person in the field by giving directions on how to repair a device. The collaborators will likely use dissimilar computers, with the person in the field having only a personal data assistant. We are primarily interested in how well the collaborators adapt to these dissimilarities in computer display and input capabilities and how well they perform the task.
The findings will help us design better human-computer interfaces in the future for this type of tasks.

To get an idea of tasks we first used real Lego pieces as a reference in order to build the tasks.

The speech synchronization was used in previous experiment of this study. In Slow Tetris Experiment we decided not to use it, but to videotape the experiment. This way allowed us better coding and coder reliability checking. We decided to tape only the doers – with this we had both conversation and the actions of the task.

Program logging remained the same as in previous experiment.

After we designed the tasks, we decided to fix the first piece / block in each task. We realized that giving to the subjects a starting point (fixed first piece in the task) will reduce the problem solving ability involved in the solution of this task.

We also decided that each piece should fit in only one position – again, the reason was reducing the task solving ability.

2.1.1. Experiment Instructions

We had to write up detailed instructions and descriptions about the Slow Tetris Experiment.

Documents are as followed: Experiment description, both for practice and the collaborative part; software guides to 2D and 3D interfaces; subject and video tape consent forms; 3D aids – pictures of 3D views of the blocks while doing the 2D interface. In addition to these documents we also created an Exit Questionnaire – that was supposed to give us more information on perception of subjects about the interfaces, partners, experiment, etc.

2.1.2. Learning Curve Studies

During the practice period, as well as while having the pilot experiments, we expected to find out the learning curve of all subjects. We realized after getting the results that there were no learning curves – we found out that the nature of the task needed a lot of task solving abilities and those couldn’t be proved in a short time period. We also found out that the 3D spatial abilities and the pattern recognition abilities are essential for the performance of the task.

The final decision was to advertise for the subject with 2D and 3D games / environment experience – for game players.

2.2 Pilot Experiments
2.2.1. First Pilot Experiment

This pilot experiment was more like testing the software. We only had one trial, i.e. four people working in pairs and collaborating. We gave them five practice tests followed by four tasks for collaboration. After this experiment we decided to give more time and tasks for practice part.

We also realized that we had to make few changes in the 2D environment: blocks on a pocket PCs were too small and we had to zoom them in; the tool pane required some modification as well.

We also had to connect indicator that will show if we are connected to the server. Colors of the blocks were too dark so that we had to fix them as well.

2.2.2. Second Pilot Experiment

This pilot experiment was held in NJIT in Newark with Information Systems students that are not familiar with computer games.

We realized that tasks in 2D environment were too hard for them to solve. They showed good performance in the in 3D environment while in 2D environment they needed more time to go through all the tasks and solve them.

Eight subjects participated in this pilot experiment, and only two of them finished tasks in the 2D environment. All eight subjects finished tasks in 3D environment.

After this pilot experiment our team faced with the dilemma: what to do now when we know that it is so hard for subjects to solve tasks in 2D environment – should we keep the 2D in the real experiment even if we know that subjects won’t be able to solve tasks; or we should drop the 2D environment and do only with the 3D interface?

It wasn’t easy to drop 2D environment from the experiment just like that. First of all, are we supposed to adjust to subjects and moderate our experiment no matter of results we want to reach – the experiment/study/research was set up with 2D environment and this interface is important for this study; of course we should take care about our subjects and don’t frustrate them with hard tasks.

What was also important that we noticed is that subjects who were not trained first in 3D environment but tried to go through tasks in 2D – they had more difficulties than those who first passed training in 3D and than in 2D. We decided for the real experiment to train all subjects – first in 3D environment and than in 2D environment!

We also decided to run few more pilot experiments and to measure exact time needed for training in 3D and 2D environment.

For this pilot experiment we had three subjects – males and all familiar with computers (i.e. with computer experience) – and it was quite easy for all of them to go through tasks. In 3D they were all very fast and showed good performance. In 2D, one of them was really very fast, while the rest two were average.

The conclusion was to leave 2D environment in the study but to direct experiment to subjects that are at least familiar with computer games and to extend period for practicing the tasks.
In this way we had actually two parts of the experiment: the practice and the collaborative part.

2.3 Practice Part
In this part of the experiment 41 subjects participated – all males drawn from the graduate and undergraduate student population. Each subject was assigned to the one of the experimenters. Subjects were first given written description of the experiment in which they found general information: description of the tasks, how to perform the tasks, basic rules for the Slow Tetris Game, etc. The second document they were given was the Subject Consent Form that subjects signed if they decided to participate in the experiment. In our experiment every subject agreed to participate. We decided to train each subject in both environments. We realized that we should train them first in 3D interface and than in 2D interface after the pilot experiments since it was easier for them to understand tasks in 3D interface than in the 2D. With having knowledge of 3D interface they new how to perform same tasks in the 2D environment.

First we gave them the description for 3D interface – Software Guide for 3D Interface. After they read this document, a verbal tutorial was given as well, where we first described them what was the experiment about with the demo of the task for which we used a special tutorial task designed only for this tutorial.

In other words, after pilot experiments we realized that we should give more explanations to the subject instead of giving them only written descriptions – we decided to give them verbal tutorials before practice tasks for each interface – what we realized was actually that they performed better when we showed them on the interface how to perform rotations and do the fit; when they were only reading descriptions, it was more difficult for them to get used to the interface; with tutorials we saw better results in practice part.

The same kind of tutorial, only adjusted to the 2D environment, was repeated before subjects started with 2D interface training. For both environments we used same 13 tasks. After subjects finished with the training part they were told that they would be contacted for the next, collaborative part. Subjects were paid for being part of this practice part as well. Results from the practice part (average time for fitting a block into the wall) were used for matching groups of four people for the collaborative part.

2.4 Collaborative Part
For this part of the experiment we invited 36 subjects already trained in the practice part. Since they already learned how to perform tasks there was no need to repeat tutorials. First we gave them description of this part of the experiment to read followed by Subject Consent forms including Video Consent form, where we explained the procedure of videotaping during the experiment and the use of this material. This document was not crucial for being the subject in this experiment. To remind them how to use interfaces we only gave them five short and easy tasks in the environment they were assigned to in the collaborative part. The tasks were chosen from
those 13 we already gave to subjects in the practice part and they were: 1, 3, 9, 10, and 11.

After they finished with this introductory phase we took subjects in two separate rooms, both equipped with speakerphones and devices (PC or PDA, depending on a role they had).

After the collaboration finished we gave them the Exit Questionnaires that were supposed to give us more information about subjects’ background, their impression about both environments, study in general, partners, general thoughts about the collaboration and the communication between people.

At the very end of the session subjects were given the “Thank You” page where we first of all thanked to our subjects for being a part of our study. On the same document we gave more defined explanation about our study and the experiment.
3 Detailed Description of Results

3.1 Performance

We capture the times to place each log through a computer logging, a review of the videos revealed that these times were inaccurate because subjects spent some time introducing each others and making sure that the experiment had stared in both of the sides of the collaboration. We used the videos and eliminated those periods. Table 1 shows the average time for fitting a blocklet for all trials.

<table>
<thead>
<tr>
<th>Communication Direction *</th>
<th>PC to PC</th>
<th>PC to PDA</th>
<th>PDA to PC</th>
<th>PDA to PDA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trial 1</td>
<td>67</td>
<td>143</td>
<td>32</td>
<td>208</td>
</tr>
<tr>
<td>Trial 2</td>
<td>31</td>
<td>74</td>
<td>132</td>
<td>128</td>
</tr>
<tr>
<td>Trial 3</td>
<td>34</td>
<td>185</td>
<td>126</td>
<td>76</td>
</tr>
<tr>
<td>Trial 4</td>
<td>89</td>
<td>62</td>
<td>88</td>
<td>41</td>
</tr>
<tr>
<td>Trial 5</td>
<td>20</td>
<td>38</td>
<td>87</td>
<td>133</td>
</tr>
<tr>
<td>Trial 6</td>
<td>48</td>
<td>57</td>
<td>38</td>
<td>171</td>
</tr>
<tr>
<td>Trial 7</td>
<td>28</td>
<td>27</td>
<td>108</td>
<td>92</td>
</tr>
<tr>
<td>Trial 8</td>
<td>83</td>
<td>99</td>
<td>71</td>
<td>49</td>
</tr>
<tr>
<td>Trial 2 discared</td>
<td>96</td>
<td>222</td>
<td>91</td>
<td>68</td>
</tr>
</tbody>
</table>

We repeated trial 2 because the PC Communicator subject had several troubles giving the instructions to the doer and this affected their performance time. As shown on Figure 1, the collaborations where the person using the PC is giving the instructions had the longer blocklet fitting time, especially for the PC to PDA that doubled the nearest fitting time for the other collaborations.

![Figure 3: Performance in trial 2 with the bad communicator.](image-url)
We dropped 13 outliers in which the number of rotations used for placing the blocklet in the right position and fitting it were 5 or more times bigger than the minimal solution. Table 1 and Table 2 show the minimal solution and the maximum rotations allowed. Any blocklet that took more than 5 times the minimum rotations is considered an outlier.

**Table 1: Minimum rotations needed for fitting the blocklets used in the four tasks solved collaboratively.**

<table>
<thead>
<tr>
<th>Blocklet</th>
<th>Blocklet 1</th>
<th>Blocklet 2</th>
<th>Blocklet 3</th>
<th>Blocklet 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Task 1</td>
<td>3</td>
<td>2</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Task 2</td>
<td>3</td>
<td>4</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Task 3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Task 4</td>
<td>3</td>
<td>4</td>
<td>4</td>
<td>3</td>
</tr>
</tbody>
</table>

**Table 2: Maximum rotations allowed. These critical values are equal to 5 times minimum rotations.**

<table>
<thead>
<tr>
<th>Blocklet</th>
<th>Blocklet 1</th>
<th>Blocklet 2</th>
<th>Blocklet 3</th>
<th>Blocklet 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Task 1</td>
<td>15</td>
<td>10</td>
<td>15</td>
<td></td>
</tr>
<tr>
<td>Task 2</td>
<td>15</td>
<td>20</td>
<td>10</td>
<td>15</td>
</tr>
<tr>
<td>Task 3</td>
<td>15</td>
<td>15</td>
<td>15</td>
<td></td>
</tr>
<tr>
<td>Task 4</td>
<td>15</td>
<td>20</td>
<td>20</td>
<td>15</td>
</tr>
</tbody>
</table>

Table 3 shows the number of rotations before fitting each blocklet in every trial. The green cells mark the blocklets fitted using the minimum possible rotations, and the red cells show the outliers.

**Table 3: Number of rotations before fitting each blocklet. The green cells are the blocklet fitting with the minimum solution, the red cells are the outliers.**

<table>
<thead>
<tr>
<th>Blocklet</th>
<th>Blocklet 1</th>
<th>Blocklet 2</th>
<th>Blocklet 3</th>
<th>Blocklet 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Task 1</td>
<td>3</td>
<td>8</td>
<td>13</td>
<td></td>
</tr>
<tr>
<td>Task 2</td>
<td>3</td>
<td>9</td>
<td>26</td>
<td>3</td>
</tr>
<tr>
<td>Task 3</td>
<td>3</td>
<td>3</td>
<td>9</td>
<td></td>
</tr>
<tr>
<td>Task 4</td>
<td>5</td>
<td>8</td>
<td>26</td>
<td>5</td>
</tr>
<tr>
<td>Trial 2</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Task 1</td>
<td>3</td>
<td>5</td>
<td>19</td>
<td></td>
</tr>
<tr>
<td>Task 2</td>
<td>10</td>
<td>7</td>
<td>10</td>
<td>3</td>
</tr>
<tr>
<td>Task 3</td>
<td>14</td>
<td>3</td>
<td>9</td>
<td></td>
</tr>
<tr>
<td>Task 4</td>
<td>3</td>
<td>4</td>
<td>6</td>
<td>3</td>
</tr>
<tr>
<td>Trial 3</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Task 1</td>
<td>3</td>
<td>19</td>
<td>21</td>
<td></td>
</tr>
<tr>
<td>Task 2</td>
<td>7</td>
<td>7</td>
<td>12</td>
<td>3</td>
</tr>
<tr>
<td>Task 3</td>
<td>5</td>
<td>3</td>
<td>3</td>
<td></td>
</tr>
</tbody>
</table>
Table 4 describes the way the information was coded for this study. All variables are numeric, without decimal digits.

**Table 4: Variables explanation and codes.**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Values</th>
<th>Value label</th>
<th>Values description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Trial</strong></td>
<td>1</td>
<td>Trial 1</td>
<td>Nominal variable that contains the number of the trial (from 1 to 8)</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>Trial 2</td>
<td></td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>Trial 3</td>
<td></td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>Trial 4</td>
<td></td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>Trial 5</td>
<td></td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>Trial 6</td>
<td></td>
</tr>
<tr>
<td></td>
<td>7</td>
<td>Trial 7</td>
<td></td>
</tr>
<tr>
<td></td>
<td>8</td>
<td>Trial 8</td>
<td></td>
</tr>
<tr>
<td><strong>Order</strong></td>
<td>1</td>
<td>First</td>
<td>Nominal variable that indicates the order of the communication directions in the trial. Each trial has 4 different combinations.</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>Second</td>
<td></td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>Third</td>
<td></td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>Fourth</td>
<td></td>
</tr>
<tr>
<td><strong>Communication</strong></td>
<td>1</td>
<td>PC to PC</td>
<td>Nominal variable that indicates the platforms used and the communication direction</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>PC to PDA</td>
<td></td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>PDA to PC</td>
<td></td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>PDA to PDA</td>
<td></td>
</tr>
<tr>
<td><strong>Time</strong></td>
<td>None</td>
<td>Time (in seconds) for fitting a</td>
<td></td>
</tr>
</tbody>
</table>
Communicator Average. Average time of the communicator in the practice for the 2D and 3D applications.

The figures above present the summary of the data collected in the 8 trials, including the trial 2 that replaced the one with the communication problems.

**Table 5: Trials summary.**

<table>
<thead>
<tr>
<th>Trial 1</th>
<th>Trial 2</th>
<th>Trial 3</th>
<th>Trial 4</th>
<th>Trial 5</th>
<th>Trial 6</th>
<th>Trial 7</th>
<th>Trial 8</th>
</tr>
</thead>
<tbody>
<tr>
<td>PC to PC</td>
<td>PDA to PDA</td>
<td>PC to PDA</td>
<td>PDA to PC</td>
<td>PC to PC</td>
<td>PDA to PDA</td>
<td>PC to PC</td>
<td>PDA to PC</td>
</tr>
<tr>
<td>67</td>
<td>143</td>
<td>32</td>
<td>208</td>
<td>133</td>
<td>74</td>
<td>185</td>
<td>88</td>
</tr>
<tr>
<td>PDA to PDA</td>
<td>PC to PC</td>
<td>PDA to PC</td>
<td>PDA to PDA</td>
<td>PC to PC</td>
<td>PDA to PDA</td>
<td>PC to PC</td>
<td>PDA to PC</td>
</tr>
<tr>
<td>132</td>
<td>128</td>
<td>136</td>
<td>89</td>
<td>87</td>
<td>74</td>
<td>126</td>
<td>99</td>
</tr>
<tr>
<td>PC to PDA</td>
<td>PC to PC</td>
<td>PC to PDA</td>
<td>PC to PC</td>
<td>PC to PDA</td>
<td>PC to PDA</td>
<td>PC to PDA</td>
<td>PC to PDA</td>
</tr>
<tr>
<td>208</td>
<td>34</td>
<td>76</td>
<td>41</td>
<td>20</td>
<td>34</td>
<td>62</td>
<td>89</td>
</tr>
<tr>
<td>PDA to PC</td>
<td>PDA to PC</td>
<td>PDA to PDA</td>
<td>PDA to PC</td>
<td>PDA to PC</td>
<td>PDA to PDA</td>
<td>PDA to PC</td>
<td>PDA to PC</td>
</tr>
<tr>
<td>208</td>
<td>89</td>
<td>41</td>
<td>62</td>
<td>74</td>
<td>99</td>
<td>49</td>
<td>71</td>
</tr>
</tbody>
</table>
## 4 Detailed Data Analysis Description

The purpose of the research was to examine the differences in performance and communication for collaborations on disparate and equal platforms. The study was divided into two parts: a standalone practice period and a collaborative trial.

Teams of four persons were formed for subjects that had approximately the same performance during the practice period. The teams were randomly assigned to one of the 8 trials. The time in seconds that it took the couple for fitting each blocklet was our independent variable, and the dependent variables were the four communication combinations. The average time for fitting a blocklet in the practice period (in both, 2D and 3D environments) was used as a covariate.

We used the following 4 by 4 ANCOVA design shown in Table 6.

### Table 6: ANCOVA design.

<table>
<thead>
<tr>
<th>Communication</th>
<th>Order in trial</th>
<th>First</th>
<th>Second</th>
<th>Third</th>
<th>Fourth</th>
</tr>
</thead>
<tbody>
<tr>
<td>PC to PC</td>
<td>6</td>
<td>7</td>
<td>6</td>
<td>8</td>
<td>27</td>
</tr>
<tr>
<td>PC to PDA</td>
<td>4</td>
<td>8</td>
<td>5</td>
<td>8</td>
<td>25</td>
</tr>
<tr>
<td>PDA to PC</td>
<td>6</td>
<td>6</td>
<td>6</td>
<td>7</td>
<td>25</td>
</tr>
<tr>
<td>PDA to PDA</td>
<td>4</td>
<td>7</td>
<td>5</td>
<td>6</td>
<td>22</td>
</tr>
<tr>
<td></td>
<td>20</td>
<td>28</td>
<td>22</td>
<td>29</td>
<td>Total:99</td>
</tr>
</tbody>
</table>

As shown in the Levene’s Test of Equality of Error Variances, the homogeneity if variance assumption was almost met with a significance level of .011.

### Table 7: Levene’s Test of Equality of Error Variances

<table>
<thead>
<tr>
<th>Levene's Test of Equality of Error Variances(a)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dependent Variable: Time for fitting the blocklet in milliseconds</td>
</tr>
<tr>
<td>F</td>
</tr>
<tr>
<td>2.232</td>
</tr>
</tbody>
</table>

Tests the null hypothesis that the error variance of the dependent variable is equal across groups.

a Design: Intercept+COMAV+COMMUNC+ORDER+COMMUNC * ORDER

The results of the Analysis of Variance found the blocklet placement time times to be significantly different for collaboration pairs F(2.70)=5.35, p<.05.

### Table 8: Tests of Between-Subjects Effects

<table>
<thead>
<tr>
<th>Tests of Between-Subjects Effects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dependent Variable: Time for fitting the blocklet in seconds</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Source</th>
<th>Type III Sum of Squares</th>
<th>df</th>
<th>Mean Square</th>
<th>F</th>
<th>Sig.</th>
</tr>
</thead>
</table>

23
A pairwise comparison of the collaboration pairs showed that the PC to PC collaboration was significantly different from either PDA to PC or PDA to PDA collaborations but that PC to PDA collaboration is only significantly different from the PDA to PC collaboration.

Table 9: Pairwise Comparisons

<table>
<thead>
<tr>
<th>(I) Communication order</th>
<th>(J) Communication order</th>
<th>Mean Difference (I-J)</th>
<th>Std. Error</th>
<th>Sig.(a)</th>
<th>95% Confidence Interval for Difference(a)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Lower Bound</td>
</tr>
<tr>
<td>PC to PC</td>
<td>PC to PDA</td>
<td>-9.614</td>
<td>12.848</td>
<td>.456</td>
<td>-35.173</td>
</tr>
<tr>
<td></td>
<td>PDA to PC</td>
<td>-49.940(*)</td>
<td>13.035</td>
<td>.000</td>
<td>-75.870</td>
</tr>
<tr>
<td></td>
<td>PDA to PDA</td>
<td>-26.955(*)</td>
<td>13.422</td>
<td>.048</td>
<td>-53.655</td>
</tr>
<tr>
<td>PC to PDA</td>
<td>PC to PDA</td>
<td>9.614</td>
<td>12.848</td>
<td>.456</td>
<td>-15.945</td>
</tr>
<tr>
<td></td>
<td>PDA to PC</td>
<td>-40.326(*)</td>
<td>13.612</td>
<td>.004</td>
<td>-67.405</td>
</tr>
<tr>
<td></td>
<td>PDA to PDA</td>
<td>-17.341</td>
<td>13.963</td>
<td>.218</td>
<td>-45.118</td>
</tr>
<tr>
<td>PDA to PC</td>
<td>PC to PC</td>
<td>49.940(*)</td>
<td>13.035</td>
<td>.000</td>
<td>24.009</td>
</tr>
<tr>
<td></td>
<td>PC to PDA</td>
<td>40.326(*)</td>
<td>13.612</td>
<td>.004</td>
<td>13.247</td>
</tr>
<tr>
<td></td>
<td>PDA to PDA</td>
<td>22.985</td>
<td>13.352</td>
<td>.089</td>
<td>-3.577</td>
</tr>
<tr>
<td>PDA to PDA</td>
<td>PC to PC</td>
<td>26.955(*)</td>
<td>13.422</td>
<td>.048</td>
<td>.254</td>
</tr>
<tr>
<td></td>
<td>PC to PDA</td>
<td>17.341</td>
<td>13.963</td>
<td>.218</td>
<td>-10.437</td>
</tr>
<tr>
<td></td>
<td>PDA to PC</td>
<td>-22.985</td>
<td>13.352</td>
<td>.089</td>
<td>-49.547</td>
</tr>
</tbody>
</table>

Based on estimated marginal means

* The mean difference is significant at the .05 level.
4.1 Communication Analysis

4.1.1. Coding instructions

For each block, put in one of the following letters

C – for Collaboration communication
T – for Takeover communication
A – for Affirmation communication
O – for One Sided communication

If you are having trouble deciding between one or more codings, write each of them down and put a question mark by them, i.e., O? A?

Here are the instructions for discerning what type of conversation is taking place.

- Collaboration: Both people are expressing their move commands as suggestions or questions. Both communicators are taking part in the problem solving and in the decision making.

- Affirmation: One decision maker is leading the conversation and telling the other person what moves to make. This is the communicator. The doer is giving approval to the decisions. This is different than simply repeating the decisions. Approval is sometimes spoken in the exchange, e.g., Top once, - Yeah, right, Nice or Good. But Approval is not always spoken. Sometimes it is in the intonation of the speaker, e.g.,
  
  Comm: Rotate top once
  Doer: Ok-a-a-a-ay! With a rising inflection on the last “ay”.
  This judgement may require listening to the tapes.

- Takeover: This is where the doer takes over the task from the Communicator. This can be seen in two ways. First, the Doer starts to suggest to the Communicator what to do. This is not done politely as it is in the collaboration exchange but without the questions and with more imperative commands. Second, the Doer may refuse to do what the Communicator is asking him to do. When this happens the Communicator gives more imperative commands asking the Doer to make the movements requested. The Doer may at this point make moves on his own.

- One Sided: In this communication exchange, the Doer is not given a chance to speak or even to give affirmations of the moves. The Communicator does all the
talking with only an occasional okay from the Doer. One sided is so blatantly one sided on the tapes that this will be easy to score.

The inter-judge reliability of this coding was .549.

Table 10: Pearson Correlations within judges

<table>
<thead>
<tr>
<th>JUDGE1</th>
<th>JUDGE2</th>
<th>JUDGE3</th>
</tr>
</thead>
<tbody>
<tr>
<td>JUDGE1</td>
<td>1</td>
<td>.676(**)</td>
</tr>
<tr>
<td>JUDGE2</td>
<td>.676(**)</td>
<td>1</td>
</tr>
<tr>
<td>JUDGE3</td>
<td>.437(**)</td>
<td>.549(**)</td>
</tr>
</tbody>
</table>

** Pearson Correlation is significant at the 0.01 level (2-tailed).

We had the judges sit and discuss their differences in the codings and come to an agreement for each of the blocklets placement. The individual codings of each judge and the final decision on the table above.

Table 11: Judges codings and final decision.

<table>
<thead>
<tr>
<th>Blocks</th>
<th>Judges decision</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>Final</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>Final</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>Final</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>PC to PC</td>
<td>A</td>
<td>O</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>T</td>
<td>A</td>
<td>A</td>
<td>T</td>
<td>A</td>
</tr>
<tr>
<td></td>
<td>PDA to PDA</td>
<td>A</td>
<td>O</td>
<td>A</td>
<td>A</td>
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26
A CHI Square analysis of the counts indicated that the distributions were significantly different at the $p<.01$ level.

**Table 12: CHI Square analysis of counts**

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* The expected frequencies are 7 for each cell.
Table 13: Average time and standard deviation of time (in seconds) for fitting the blocklets during the practice period for the 2D and the 3D environments, and average fitting time.

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## APPENDIX B

Table 14: Performance data in 8 trials without outliers.

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<td>23</td>
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</table>
7 APPENDIX C

7.1 Tutorial and Practice Tasks

cWorld left view of Tutorial
cWorld front view of Tutorial

Pocketscape top view of Tutorial
Pocketscape front view of Tutorial
cWorld left view of Practice 6

cWorld front view of Practice 6

cWorld right view of Practice 6

Pocketscape top view of Practice 6

Pocketscape front view of Practice 6
cWorld left view of Practice 7

Pocketscape top view of Practice 7

Pocketscape front view of Practice 7

Pocketscape front view of Practice 7

cWorld front view of Practice 7

cWorld right view of Practice 7
cWorld left view of Practice 11

cWorld front view of Practice 11

cWorld right view of Practice 11

Pocketscape top view of Practice 11

Pocketscape front view of Practice 11
cWorld left view of Practice 13

cWorld front view of Practice 13

cWorld right view of Practice 13

Pocketscape top view of Practice 13

Pocketscape front view of Practice 13
8 APPENDIX D

8.1 Collaborative Tasks

- cWorld left view of Test 1
- cWorld front view of Test 1
- cWorld right view of Test 1
- Pocketscape top view of Test 1
- Pocketscape front view of Test 1
cWorld left view of Test 3

cWorld front view of Test 3

cWorld right view of Test 3

Pocketscape top view of Test 3

Pocketscape front view of Test 3
cWorld left view of Test 4  
cWorld front view of Test 4  
cWorld right view of Test 4  
Pocketscape top view of Test 4  
Pocketscape front view of Test 4
9 APPENDIX E

9.1 Experimenters’ Documents
# Experiment Log Sheet

Date: 

Experimenter Name: 

This is a log of any unexpected events taking place during the experiment. For example:
   The computer does not respond.
   The window is not responding.
   The subject broke the rules.

<table>
<thead>
<tr>
<th>Time</th>
<th>Event</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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</table>
## General Check List

<table>
<thead>
<tr>
<th>All subjects are available.</th>
</tr>
</thead>
<tbody>
<tr>
<td>You have keys of all rooms.</td>
</tr>
<tr>
<td>Prepare the rooms; check speakerphones (line is Ok), place tables and chairs, light.</td>
</tr>
<tr>
<td>Laptops and PocketPCs are connected to the network and the software is working.</td>
</tr>
<tr>
<td>Laptops and PocketPC volume level for the PC beep is high.</td>
</tr>
<tr>
<td>PocketPC screens are recalibrated.</td>
</tr>
<tr>
<td>PocketPC and laptop screens are clean.</td>
</tr>
<tr>
<td>PocketPC are placed in a position where they can be video taped and the positions are comfortable for the users.</td>
</tr>
<tr>
<td>Cameras are in right positions and tapes are in (verify that you know how to operate it). Do a mini recording and playback.</td>
</tr>
<tr>
<td>Batteries or connections for:</td>
</tr>
<tr>
<td>Video Cameras</td>
</tr>
<tr>
<td>PocketPC</td>
</tr>
<tr>
<td>Laptops</td>
</tr>
<tr>
<td>Time in PocketPC, Laptop and cameras is synchronized.</td>
</tr>
<tr>
<td>Stopwatches are prepared.</td>
</tr>
<tr>
<td>Copies of the documents are prepared:</td>
</tr>
<tr>
<td>Subject Assignment Form (1 page)</td>
</tr>
<tr>
<td>Experiment Script (2 pages)</td>
</tr>
<tr>
<td>SlowTetris Collaboration Experiment description (2 pages)</td>
</tr>
<tr>
<td>Guide to the 3D Interface (3 pages)</td>
</tr>
<tr>
<td>Guide to the 2D Interface (4 pages)</td>
</tr>
<tr>
<td>Subjects Consent Form (1 page)</td>
</tr>
<tr>
<td>Videotape Consent Form (1 page)</td>
</tr>
<tr>
<td>M.R.T. Test: Experiment description, part I and Part II (3 sheets)</td>
</tr>
<tr>
<td>Experiment Log Sheet (1 page)</td>
</tr>
<tr>
<td>3D views pictures (14 pages)</td>
</tr>
<tr>
<td>Subject Schedule Form (1 page)</td>
</tr>
<tr>
<td>Subject Schedule with the following information: Name, experimenter, platform (cWorld or PocketScape), room, phone number, test to be open, user login, password, and server name or Address and Port.</td>
</tr>
</tbody>
</table>
Subject Schedule Form

Subject name: 
Role: Doer Communicator
Platform: PC Pocket PC
Room and phone number:

Partner name | Experimenter name | Platform (PC or PocketPC) | Room | Phone number | Test file | Open test (y/n) | Use tranf. (y/n) |
-------------|------------------|---------------------------|------|--------------|-----------|----------------|----------------|

You should open the test if:
The subject is working in CWorld and has the Communicator role.
The subject is working in CWorld and his or her partner is working on PocketScape.
The subject and his or her partner are working in PocketScape, and the subject has the Communicator role.

Login information

Login
Password
Address
Server name
Port

Login assignment table

<table>
<thead>
<tr>
<th>PC</th>
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<th>Doer</th>
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</thead>
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<tr>
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<td>user2</td>
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<tr>
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<td>user3</td>
<td>user4</td>
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### Subject Assignment Form

Date and time: 

Sequential number: _______________  Trial: _____________

<table>
<thead>
<tr>
<th>Trial Combination</th>
<th>Communicator</th>
<th>Room and Phone</th>
<th>Doer</th>
<th>Room and Phone</th>
<th>Test Assigned</th>
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List of the independent variables presentation for each trial.

#### Trial 1
- PC → PC
- PC → PocketPC
- PocketPC → PC
- PocketPC → PocketPC

#### Trial 2
- PocketPC → PocketPC
- PC → PocketPC
- PocketPC → PC
- PC → PC

#### Trial 3
- PocketPC → PC
- PC → PocketPC
- PocketPC → PocketPC
- PC → PocketPC

#### Trial 4
- PC → PocketPC
- PocketPC → PC
- PC → PC
- PocketPC → PocketPC

#### Trial 5
- PocketPC → PocketPC
- PC → PocketPC
- PC → PC
- PocketPC → PocketPC

#### Trial 6
- PocketPC → PC
- PC → PocketPC
- PC → PC
- PocketPC → PocketPC

#### Trial 7
- PC → PC
- PC → PocketPC
- PocketPC → PocketPC
- PocketPC → PC

#### Trial 8
- PC → PocketPC
- PocketPC → PocketPC
- PocketPC → PC
- PC → PC
10APPENDIX F

10.1 Subjects’ Documents
**SlowTetris Practice Experiment Description**

**Introduction**
We will ask you to carry out 13 different small tasks. The tasks complexity increases from two pieces at the beginning to three pieces the end. You are going to use two different devices, a PC that offers you a three-dimensional view of the task and a Pocket PC with two-dimensional views.

**The Task**
The task for you is to build a block wall in the minimum time possible using odd shape wall pieces. We call these pieces blocklets. Each blocklet will be a different color and the number of blocklets that form a wall will vary from 2 to 3 pieces. You have to rotate and fit the blocklets to form the wall.

An example of three blocklets at the beginning of the task, before they are joined into a wall, looks as follows:

![3D View](image)

![2D front view](image)

![2D top view](image)

The first (red blocklet in the picture above) blocklet starting from left to right is always fixed and you can’t change its position. Other blocklets will be given in the order they should be fit in the wall.

For example, using the above picture, you can’t rotate or fit the green blocklet into the wall until the yellow one is already fit into the wall. Note that the individual blocklets forming the wall are not square. In the 2D front view (see picture above) you can observe that they are larger in the left to right direction than in the bottom to top direction. There is only one correct way to place each blocklet into the wall.
The Rules
The following rules apply to the task:
- The first blocklet cannot be rotated.
- Place the blocklets into the wall in the order they are given to you.

Data collection
We are going to measure the time it takes you to finish the wall correctly. Work as quickly and accurately as you can. All data collected in the experiment will be stored so as to preserve your privacy and confidentiality. This information will help us to improve the design of software for mobile communication tasks.

Thank you for your collaboration.
Subject Consent Form
SLOWTETRIS Experiment

I have read the Description of the SLOWTETRIS Experiment and understand what tasks are expected of me in the experiment. I also fully understand that all data collected in the experiment will respect my confidentiality and privacy and that I am free to quit the experiment at any time.

I am willing to participate in the experiment and have relevant information recorded on my participation.

Name (please print): ____________________________________________
Telephone: ___________________________________________________
Email: _______________________________________________________
Signature: ____________________________________________________
Date: ________________________________________________________

If you have any questions about your rights as a research subject, you may contact the Office of Research and Sponsored Programs at 732/932-0150 ext. 2104.

Individual directing the experiment:

Professor Ivan Marsic
CAIP
Rutgers University
Piscataway, NJ
Tel: (732) 445-6399
Email: marsic@caip.rutgers.edu

Copy for CAIP
Subject Consent Form
SLOWTETRIS Experiment

I have read the Description of the SLOWTETRIS Experiment and understand what tasks are expected of me in the experiment. I also fully understand that all data collected in the experiment will respect my confidentiality and privacy and that I am free to quit the experiment at any time.

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Date: _________________________________________________________

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Individual directing the experiment:

Professor Ivan Marsic
CAIP
Rutgers University
Piscataway, NJ
Tel: (732) 445-6399
Email: marsic@caip.rutgers.edu

Copy for Subject
Videotape Consent Form  
SLOWTETRIS Experiment

Sometimes it is very useful for us to use one of our experiment videotapes in presentations to other researchers. If we do this with the videotape we are taking of you, it is likely that we will show this videotape to audiences as large as 500 people. We will in no way identify you in the videotape and only the screen activities coupled with your speech will be visible. However, to show this videotape, we need your permission.

I have read the above usage proposed for the videotape of this study and understand that no image of me will appear in the videotape. I agree to the usage of this videotape for research purposes only.

Note: You may participate in the Slow Tetris Experiment whether or not you agree to be videotaped.

Name (please print): ____________________________________________

Signature: ____________________________________________________

Date: ________________________________________________________

If you have any questions about your rights as a research subject, you may contact the Office of Research and Sponsored Programs at 732/932-0150 ext. 2104.

Individual directing the experiment:

Professor Ivan Marsic  
CAIP  
Rutgers University  
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Signature: ____________________________________________________
Date: ________________________________________________________

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Individual directing the experiment:

Professor Ivan Marsic
CAIP
Rutgers University
Piscataway, NJ
Tel: (732) 445-6399
Email: marsic@caip.rutgers.edu

Copy for Subject
Guide to the 3D Interface

INTRODUCTION
In the 3D interface, you are looking at:
1. A toolbar with tools to rotate the blocklets and fit them together;
2. The blocklets (odd shape blocks that fit together);
3. A set of three arrows in the bottom of the screen that allows you to switch between different views of the blocklets.

TOOLBAR
In the 3-dimensional interface, only one of the tools is active at a given time. You can activate a tool by clicking on its button. When a tool is activated, its background will turn white.

TOOLBAR
To apply the active tool to a blocklet, you have to click on the blocklet you want to rotate or fit into the wall.
These two buttons are used to open files and connect to the server. Do not use these buttons unless directed to do so by the experimenter.

The following are the tools you will use to rotate and fix the objects. Remember that the first blocklet from left to right is in the correct position and can’t be rotated.

This tool rotates the selected blocklet 90 degrees (a quarter of a circle) from the top, as shown in the picture below:

![Before rotating](image1.png)  ![After rotating](image2.png)

This tool rotates the selected blocklet 90 degrees (a quarter of a circle) from the front, as shown in the picture below:

![Before rotating](image3.png)  ![After rotating](image4.png)
Once you have rotated the blocklet to the correct position, fit it into the wall using the **Fit** button. If the Blocklet is not in the right position, you will hear a beep. Once you fit the blocklet into the wall you cannot rotate it again. After clicking the blocklet that you want fit, you will return to the last rotation tool that you had selected.

**FIT**

**Before fitting**

**After Fitting**

**VIEWS**

You will have three different views to see the wall: left, front and right. You can switch between them by clicking the arrows that are in the bottom of the window.

**Left view (left arrow selected)**

**Front view (center arrow selected)**
Guide to the 2D Interface

INTRODUCTION

In the 2D interface, you are looking at one of three tabbed panes that contain:

1. The tools,
2. The top view and
3. The front view of the blocklets.

![Tabbed panes](image)

**2D screen**

You can switch between the tools and the views by selecting the appropriate tab in the bottom of the tabbed pane.

This is a picture example of how the same sets of blocklets are seen from two different views and what these blocklets look like in 3D.

![2D Top view](image) ![2D Front view](image)

For each of the practice tasks you will perform, we will give you a 3D picture of the blocklets used in the task to help you orient your self to the 2D representation. Look at the 3D view and familiarize yourself with the color differences that show depth in the 2 dimensional views.
You can rotate objects and place them into the wall. Space within the shaped object that is other color than the object itself represents emptiness or the space far away from you.

**TOOLBAR**
The tools you’re going to use to rotate and fit blocklets are found in the 2d toolbar. In the 2D toolbar, only one of the tools is active at a given time.

You can activate a tool by clicking on its button. A reverse video image of the button indicates that the tool has been selected and activated.

To apply the active tool to a blocklet, you have to select the top or front view and then click on the blocklet you want to rotate or fit into the wall. You can switch between the tools and the views by selecting the appropriate tab in the tabbed pane.

Note that there is an icon in the upper right corner of the screen that indicates you what tool (rotate or fit) is active at the time. You will see this icon even when you are in a different view as shown in the picture bellow.

These buttons are used to open files and connect to the server. Do not use these buttons unless directed to do so by the experimenter.
The following are the tools you will use to rotate and fix the objects. Remember that the first blocklet from left to right is in the correct position and can’t be rotated.

This tool rotates the selected blocklet 90 degrees (a quarter of a circle) counter clockwise in the actual view. In the following example, you will see the top view before and after the yellow blocklet is rotated.

Keep in mind that when you rotate an object in one of the views, the image in the other view change also. In the example above, the top view is as follows:

**Front View**

**Before Rotation**

![Before Rotation Image]

**After Rotation**

![After Rotation Image]

The corresponding 3D view of this rotation in the Top view is:

**3D View**

**Before Rotation**

![Before Rotation 3D Image]

**After Rotation**

![After Rotation 3D Image]
Once you have rotated the blocklet to the correct position, fit it into the wall using the **Fit** button. Once you fit the blocklet into the wall you cannot rotate it again. The following is an example of what is seen before and after fitting the yellow blocklet in the wall.

### Top view

![Top view Before Fit](image1)

![Top view After Fit](image2)

### Front View

![Front View Before Fit](image3)

![Front View After Fit](image4)
SlowTetris Experiment Description

Introduction
The experiment will involve you and two other people who have also volunteered to participate in this study. You will be communicating with them by speakerphone about the computer tasks we will ask you to perform jointly.
Before the experiment, we will be giving you 5 practice tasks to help you in getting familiar with the computer tasks. When you have finished the practice tasks, we will ask you to carry out similar type, but more complex tasks with a partner. Your partner may not have the same view of each task that you do because he or she may uses a different computer device. It is up to both of you to communicate effectively about what you are seeing and what needs to be done to accomplish the tasks.

The Task
The task for you and your partner is to build a block wall in the minimum time possible using odd shape wall pieces. We call these pieces blocklets. Each blocklet will be a different color and the number of blocklets that form a wall will vary from 4 to 5 pieces.
User 1 (Communicator) will direct User 2 (Doer) on how to rotate and move the blocklets to form the wall.
Only the doer can move the objects and fit them into the wall.

An example of three blocklets at the beginning of the task, before they are joined into a wall, looks as follows:

3D View

2D front view

2D top view

The first (red blocklet in the picture above) blocklet starting from left to right is always fixed and you can’t change its position. Other blocklets will be given in the order they should be fit in the wall. For
example, using the above picture, you can’t rotate or fit the green blocklet into the wall until the yellow one is already fit into the wall.

Note that the individual blocklets forming the wall are not square. In the 2D front view (see picture above) you can observe that they are larger in the left to right direction than in the bottom to top direction. **User 2 (doer)** will rotate the blocklets following the directions of **User 1 (communicator)**. There is only one correct way to place each blocklet into the wall.

**The Rules**
The following rules apply to the task:
- **The Communicator (User 1)** can only watch and give instructions.
- Only **the Doer (User 2)** can rotate and fit the objects according to the directions of the communicator, Doers should not work on their own but can make suggestions to their communicator.
- Place the blocklets into the wall in the order they are given to you.

**Data collection**
We are going to measure the time it takes you to finish the wall correctly. Work as quickly and accurately as you can.
During the experiment we will be also videotaping, **the Doer** of the task. All data collected in the experiment will be stored so as to preserve your privacy and confidentiality. This information will help us to improve the design of software for mobile communication tasks.

Thank you for your collaboration.
Exit Questionnaire
2D-3D Collaboration Experiment

Please answer the following questions about the experiment, and please try to be as honest and direct in your responses as you can be. Having an honest evaluation of our work is critical for our research. Thank you.

Personal Information

1. Name: _______________________________________________________________

2. Email: _______________________________________________________________

3. Telephone number(s): Work: __________________ Home: __________________

4. Department/Field of Study: _______________________________________

5. Undergraduate _____ or Graduate _____ student [check one]

Background

6. How long have you been using computers? _______ years.

7. Do you have experience playing any video games? (e.g., any type of PC-based games, Nintendo/Sony Playstation games, etc.) ___ Yes ___ No

If you answered “yes” to the above question, please answer the following follow-up questions:

7a. For how long have you been playing video games? _______ years

7b. How often do you play video games? (circle one)
   A. Less than one hour per week
   B. Between one and five hours per week
   C. Between five and ten hours per week.
   D. Over ten hours per week.
8. Please circle all of the input devices that you have used:

A. Joystick          E. Game Cube
B. Sony Playstation   F. Nintendo
C. Sony Playstation 2 G. GameBoy
D. X-Box             H. Nintendo

9. Do you have any experience with virtual environments?  ___ Yes ___ No

10. Do you have any experience with 3D computer programs? ___ Yes ___ No

11. Please indicate your age group: (circle one)

< 18  26 – 30  41 – 45
18 – 20  31 – 35  46 – 50
21 – 25  36 – 40  > 50

The 2D Application:

Answer the following questions by circling the number which best represents your opinions about the study.

On a scale from 1 to 7, 1 being the lowest score and 7 being the highest, please rate the following:

1. I found the 2D application easy to use.

   1  2  3  4  5  6  7
Strongly Disagree           Strongly Agree

2. The 2D display sometimes confused me.

   7  6  5  4  3  2  1
Strongly Agree               Strongly Disagree

3. It was easy to learn how to manipulate objects in the 2D environment.

   1  2  3  4  5  6  7
Strongly Disagree             Strongly Agree

4. In 2D, I found it difficult to collaborate with my partner when he was also using a 2D application.

   7  6  5  4  3  2  1
Strongly Agree               Strongly Disagree
5. In 2D, I found it difficult to collaborate with my partner when he was using a 3D application.

1  2  3  4  5  6  7
Strongly Disagree                      Strongly Agree

6. I liked using the 2D environment.

1  2  3  4  5  6  7
Strongly Disagree                      Strongly Agree

For question 6, please elaborate:

______________________________________________________________________
______________________________________________________________________
______________________________________________________________________
______________________________________________________________________
______________________________________________________________________
______________________________________________________________________

The 3D Application:

7. I found the 3D application easy to use.

1  2  3  4  5  6  7
Strongly Disagree                      Strongly Agree

8. The 3D display sometimes confused me.

7  6  5  4  3  2  1
Strongly Agree                         Strongly Disagree

9. It was easy to learn how to manipulate objects in the 3D environment.

1  2  3  4  5  6  7
Strongly Disagree                      Strongly Agree

10. In 3D, I found it difficult to collaborate with my partner when he was also using a 3D application.

1  2  3  4  5  6  7
Strongly Disagree                      Strongly Agree
11. In 3D, I found it difficult to collaborate with my partner when he was using a 2D application.

<table>
<thead>
<tr>
<th>Strongly Agree</th>
<th>7</th>
<th>6</th>
<th>5</th>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
<th>Strongly Disagree</th>
</tr>
</thead>
</table>

12. I liked using the 3D environment.

<table>
<thead>
<tr>
<th>Strongly Disagree</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>Strongly Agree</th>
</tr>
</thead>
</table>

For question 12, please elaborate:

______________________________________________________________________

______________________________________________________________________

______________________________________________________________________

______________________________________________________________________


The Roles—Communicator vs. Doer:

My role in this experiment was (check one): Communicator _____ or Doer _____

13. I found it easier to perform the task when using (check one):

____ 2D environment _____ 3D environment

14. Communicator:  I found it easy to communicate the instructions

        Doer:  I found it easy to understand the instructions

<table>
<thead>
<tr>
<th>Strongly Disagree</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>Strongly Agree</th>
</tr>
</thead>
</table>

15. Communicator:  I found it easier to give instructions when I was using

        Doer:  I found it easier to understand instructions when I was using

____ 2D environment _____ 3D environment
16. Communicator: I found it easier to give instructions when my partner was using
Doer: I found it easier to understand instructions when my partner was using

____ 2D environment  ____ 3D environment

17. The system provided an effective and efficient means to accomplish the tasks.

1  2  3  4  5  6  7
Strongly Disagree  Strongly Agree

18. What other information should the system provide to enhance collaboration?

______________________________________________________________________
______________________________________________________________________
______________________________________________________________________
______________________________________________________________________
______________________________________________________________________

19. If you were designing the system, what would you have done differently?

______________________________________________________________________
______________________________________________________________________
______________________________________________________________________
______________________________________________________________________
______________________________________________________________________
Impressions About Your Partner:

20. My partner seems to be intelligent:

1  2  3  4  5  6  7
Strongly Disagree           Strongly Agree

21. My partner seems to be honest:

1  2  3  4  5  6  7
Strongly Disagree           Strongly Agree

22. My partner seems to be fair:

1  2  3  4  5  6  7
Strongly Disagree           Strongly Agree

23. I think I can collaborate well with this partner:

1  2  3  4  5  6  7
Strongly Disagree           Strongly Agree

24. My impression is that this partner is rational:

1  2  3  4  5  6  7
Irrational                 Rational

25. Please indicate your overall impression of your partner:

1  2  3  4  5  6  7
Untrustworthy              Trustworthy

26. Please indicate your overall impression of your partner:

1  2  3  4  5  6  7
Weak                       Powerful

27. Please indicate your overall impression of your partner:

1  2  3  4  5  6  7
Unkind                     Kind
28. Please indicate your overall impression of your partner:

1 2 3 4 5 6 7
Unfriendly  Friendly

29. Please indicate your overall impression of your partner:

1 2 3 4 5 6 7
Rigid  Flexible

30. My partner seemed to be aggressive:
(Partner is Unaggressive,)

1 2 3 4 5 6 7
Strongly Disagree  Strongly Agree

31. My partner was helpful when performing the task:

1 2 3 4 5 6 7
Strongly Disagree  Strongly Agree

32. Please indicate your impression about the cooperativeness of your partner:

1 2 3 4 5 6 7
Competitive  Cooperative

33. Please indicate your overall impression of your partner:

1 2 3 4 5 6 7
Cold  Warm

34. Please indicate your overall impression of your partner:

1 2 3 4 5 6 7
Manipulative  Sincere

35. Please indicate your overall impression of your partner:

1 2 3 4 5 6 7
Selfish  Unselfish
General Thoughts:

36. The experiment took too long.

   1  2  3  4  5  6  7
Strongly Disagree                 Strongly Agree
37. Please provide any other suggestions or comments that you might have.

______________________________________________________________________
______________________________________________________________________
______________________________________________________________________
______________________________________________________________________
______________________________________________________________________

Please answer the following questions by indicating how you personally feel about each statement from 1 – 7, with 1 being Strongly Disagree and 7 being Strongly Agree.

38. In dealing with strangers one is better off being cautious until you have evidence that the stranger is trustworthy.

1  2  3  4  5  6  7
Strongly Disagree Strongly Agree

39. In these competitive times, one has to be alert or someone is likely to take advantage of you.

1  2  3  4  5  6  7
Strongly Disagree Strongly Agree

40. Society will fall apart if police power that counters criminal activities weakens.

1  2  3  4  5  6  7
Strongly Disagree Strongly Agree

41. One should not trust others until one knows them well.

1  2  3  4  5  6  7
Strongly Disagree Strongly Agree

42. Most people tell a lie when they can benefit from doing so.

1  2  3  4  5  6  7
Strongly Disagree Strongly Agree
43. When someone says something complimentary about you it's because they want to get something from you.

1  2  3  4  5  6  7
Strongly Disagree  Strongly Agree

44. People will take advantage of you if you cooperate with them.

1  2  3  4  5  6  7
Strongly Disagree  Strongly Agree

45. Given the opportunity, people are dishonest.

1  2  3  4  5  6  7
Strongly Disagree  Strongly Agree
Thank you for participating in this experiment.

We asked you to collaborate on moving virtual blocks around to build a wall. The task simulates a real-world problem of an office-bound help-desk person assisting a person in the field by giving directions on how to repair a device. The collaborators will likely use dissimilar computers, with the person in the field having only a personal data assistant. We are primarily interested in how well the collaborators adapt to these dissimilarities in computer display and input capabilities and how well they perform the task. The findings will help us design better human-computer interfaces in the future for this type of tasks.

If you have any complaints or questions about this experiment you may contact:

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or

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Rutgers University  
732/932-0150 ext. 2104.