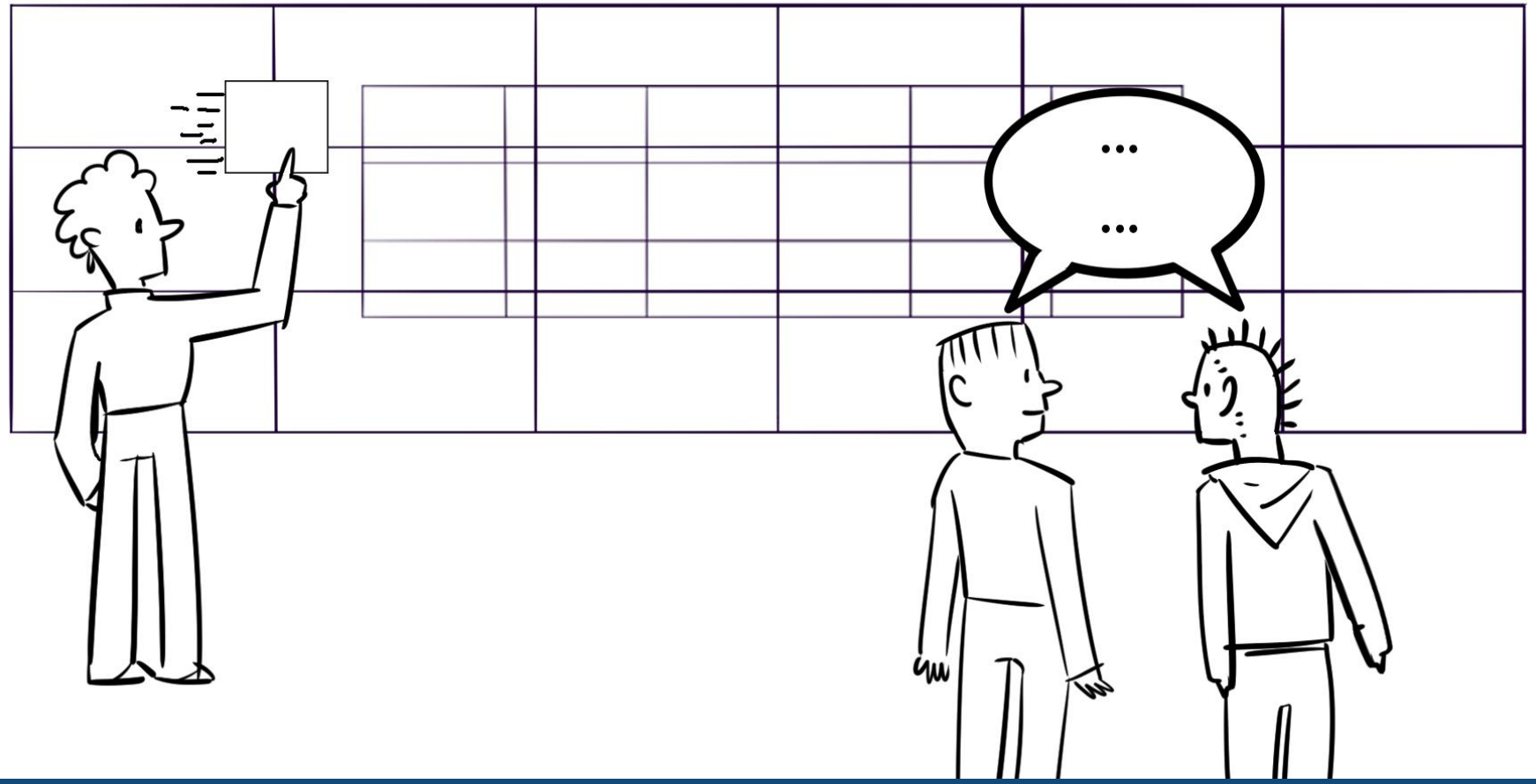

Large Multi-touch Vertical Displays in Multi-user Competitive Tasks

Davide Tantillo
Advisors: Prof. G. Elisabeta Marai (UIC)
Prof. Franca Garzotto (Politecnico di Milano)

Objectives

Given:

- a **multi-user** environment;
- a task both **collaborative** and **competitive**;
- a **large multi-touch vertical display** (LMVD) to assist humans in solving the task.

Provide an extensive description of:

- the advantages and disadvantages of using a LMVD compared to the traditional way of solving the task;
- the **human** and **group behavior** while using the LMVD in these conditions.

Outline

- Introduction
- The task
- Implementation (quick demo)
- Results
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Why are large vertical displays (LVD) used?

- **Very wide resolution**:
  - ➢ A lot of information at the same time;
  - ➢ More users simultaneously (both active/passive);
- **Attractive** (Fair and exhibition)**;**
- **Touch interaction**:
  - ➢ More attractive;
  - ➢ Useful.

Known Problems and current solutions (1/2)

- **Displaying information**: it is not easy to let the user consume data and information.

Current solution: Data Visualization.

- **Application context**: where should large display applications run? OS vs dedicated environment?

Current solution: Few studies, but interesting solutions (for example, SAGE2).

Known Problems and current solutions (2/2)

- **Application interface**: how to organize an interface for an LVD? Is the interface dependent on the input system?
- **Human Interaction:** how do users behave with LVDs?

Why  ?

1) Large vertical displays **need their own interface paradigm**[1];
2) The current studies are too in-depth and forgot to make a comparison with other studies. It resulted in having an inconsistent literature[2].

[1] Moreland, Kenneth. "Redirecting research in large-format displays for visualization."
[2] Knudsen, Søren, Mikkel Rønne Jakobsen, and Kasper Hornbæk. "An exploratory study of how abundant display space may support data analysis."

Outline

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The conference scheduling problem (1/3)

My problem instance

The scheduling session for talks in a scientific conference

$\in$

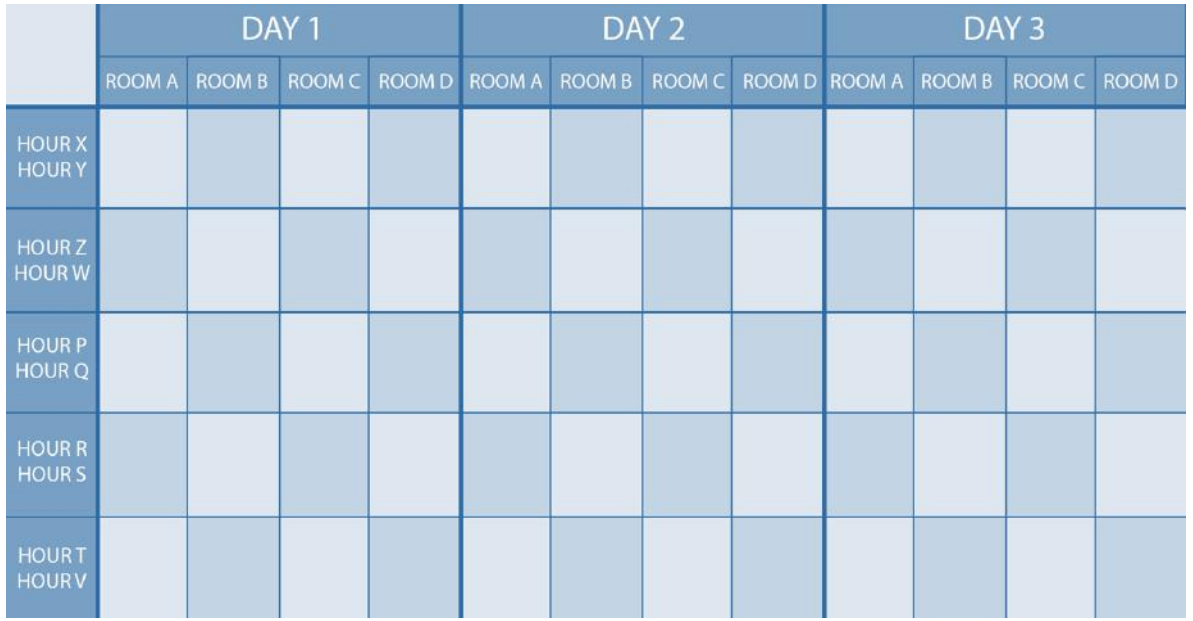
Problem family

Large Vertical Displays:
- Multitouch
- Multi-user
- Competitive (not fully)

The conference scheduling problem (2/3)

Given:

- **X**, scientific topics;
- **A**, days;
- **B**, slot hours;
- **C**, rooms;
- **D**, papers;
- **E**, constraints;



- Each paper **d** has a scientific topic **x**;
- Each paper **d** has **numeric value**;
- Each constraint **e** is associated to a paper **d**;
- There are **AxBxC slots** where paper can be inserted; each of them has a **numeric value**.

The conference scheduling problem (3/3)

Goal: **to find an admissible schedule** in which:

- All the papers have a slot;
- All the constrains are respected;
- Maximize the schedule value that is calculated as:
  Sum of all the products between the paper value and the value of the cell occupied by the paper.

Why people still organize conference scheduling by themselves

A comparison with a well-know **NP-Hard problem** (Time Table Design Problem[a]) can be done. It means that it is **not possible to solve this problem algorithmically in polynomial time**.

However, efficient heuristics providing high-score solutions exist.

- Why do people still organize conference by themselves?

  This is necessary to create a **flow** that allows each kind of attendee to enjoy the conference.

[a] Garey and Johnson – Computers and Intractability – p. 243

The procedure: two phases

There is a participant for each scientific topic

Once created the scheduling table, there are two phases:

- **First Phase** (turn-based):
  - With a turn-based approach, each participant places one of his papers on a free slot;
  - Constraints can be violated in this phase. Indeed, a participant might be obligated to violate a constraint.
- **Second Phase** (negotiation):
  - Participants try to satisfy their constraints and improve the position of some papers;
  - To do it, they can start a conversation to negotiate the desired slots.

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The study interests

- Are **LVDs more efficient** than the **traditional approach** to solve the conference scheduling problem?

- **How people behave** with an LMVD in a multi-user competitive environment.

The measures of interest are:

- **Display Proximity;**
- **Verbal communication;**
- **Visual attention;**
- **Group shape;**
- **Display usage**.

} As a group

Task results

Task results for each group and approach									
Group	**Ap-proach**	**Overall Score**	**P1**	**P2**	**P3**	**P4**	**Time**	**1st ph. time**	**2nd ph. time**
G1	Trad.	143	35	35	35	**38**	19m55s	11m17s	8m38s
G2	Trad.	142	**42**	38	27	35	16m37s	10m05s	6m32s
G3	Trad.	140	33	34	36	**37**	31m27s	12m21s	19m06s
G4	Trad.	141	36	39	29	**37**	28m35s	9m06s	19m29s
G5	Trad.	141	37	**38**	34	32	39m57s	11m41s	28m16s
G1	Display	142	34	35	33	**42**	10m39s	9m26s	1m13s
G2	Display	143	38	38	**39**	28	29m27s	10m26s	19m01s
G3	Display	143	**37**	36	35	35	32m07s	11m26s	20m41s
G4	Display	139	29	**38**	36	36	30m22s	10m25s	20m07s
G5	Display	145	36	35	**37**	**37**	35m25s	13m57s	21m28s

Task results

Task results for each group and approach									
Group	**Approach**	**Overall Score**	**P1**	**P2**	**P3**	**P4**	**Time**	**1st ph. time**	**2nd ph. time**
G1	Trad.	143	35	35	35	**38**	19m55s	11m17s	8m38s
G2	Trad.	142	**42**	38	27	35	16m37s	10m05s	6m32s
G3	Trad.	140	33	34	36	**37**	31m27s	12m21s	19m06s
G4	Trad.	141	36	39	29	**37**	28m35s	9m06s	19m29s
G5	Trad.	141	37	**38**	34	32	39m57s	11m41s	28m16s
G1	Display	142	34	35	33	**42**	10m39s	9m26s	1m13s
G2	Display	143	38	38	**39**	28	29m27s	10m26s	19m01s
G3	Display	143	**37**	36	35	35	32m07s	11m26s	20m41s
G4	Display	139	29	**38**	36	36	30m22s	10m25s	20m07s
G5	Display	145	36	35	**37**	**37**	35m25s	13m57s	21m28s

Variances are similar

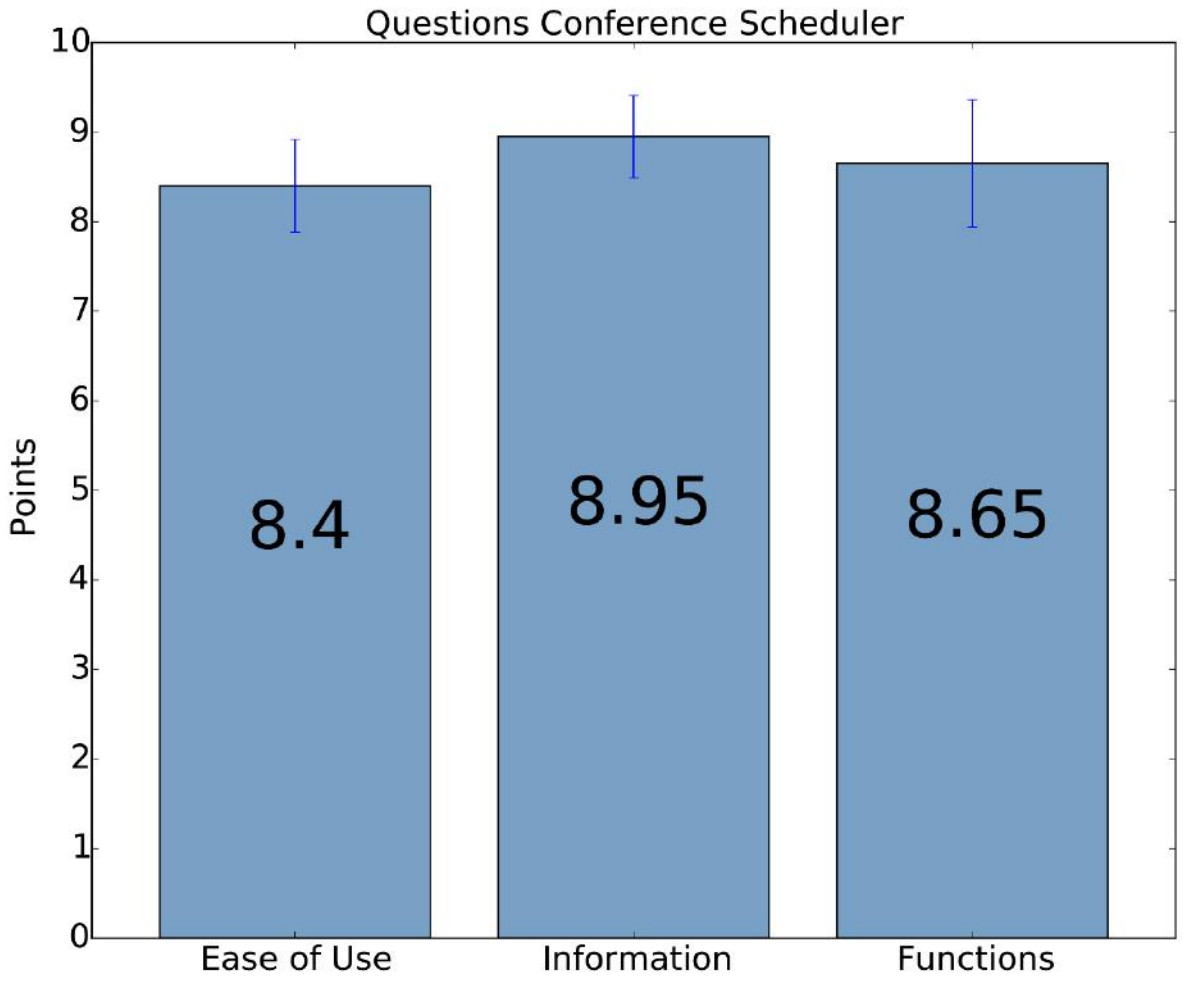
Also the growth of the points

Questionnaires (1/3)

Users rated the Conference Scheduler application on the:

- **Ease of use**;
- Quality of **visualized information**;
- Quality of offered **functions**;

With votes between 8 and 9 (SD between 0.5 and 0.7);

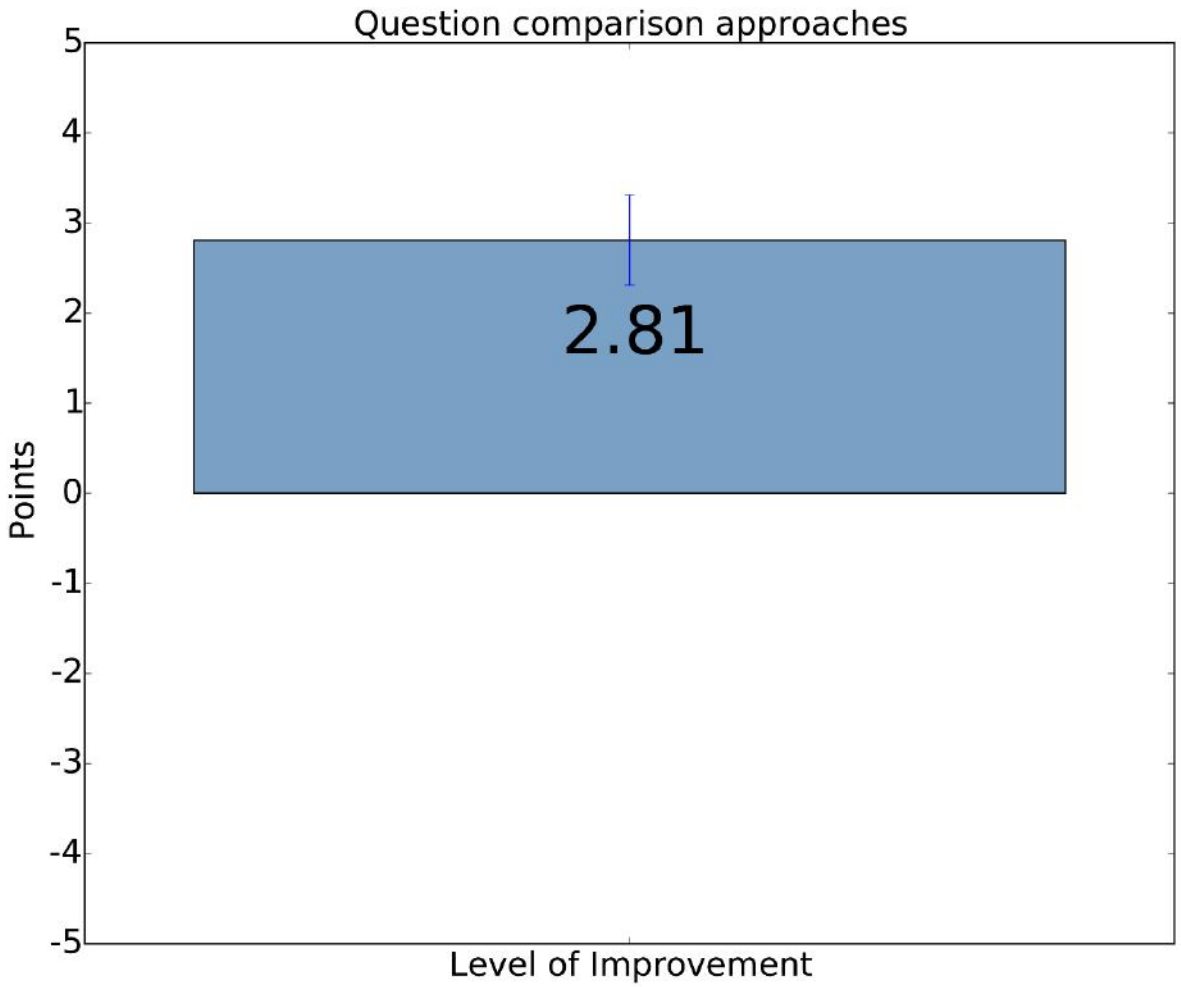


Questionnaires (2/3)

Users rated the:

- **level of improvement**

offered by the **Conference Scheduler** application compared to the **traditional approach** with an average of 2.81 (SD=0.5)



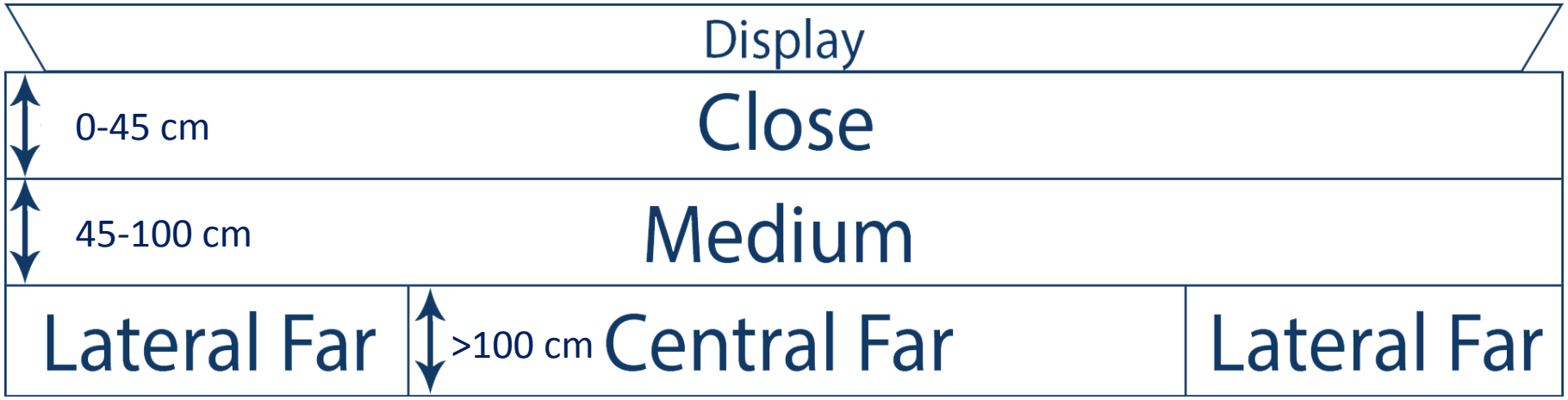
Questionnaires (3/3)

Answers to the open question on the preference of the display approach:

- It was **more clear**, more **flexible** and **customizable**;
- Possibility to move items around the display space;
- Technological approach **reduces errors**;
- **Easier to undo** an action;
- Possibility to **reduce the setup times** and usage of material;
- It is the future;
- It was more fun.

Display proximity

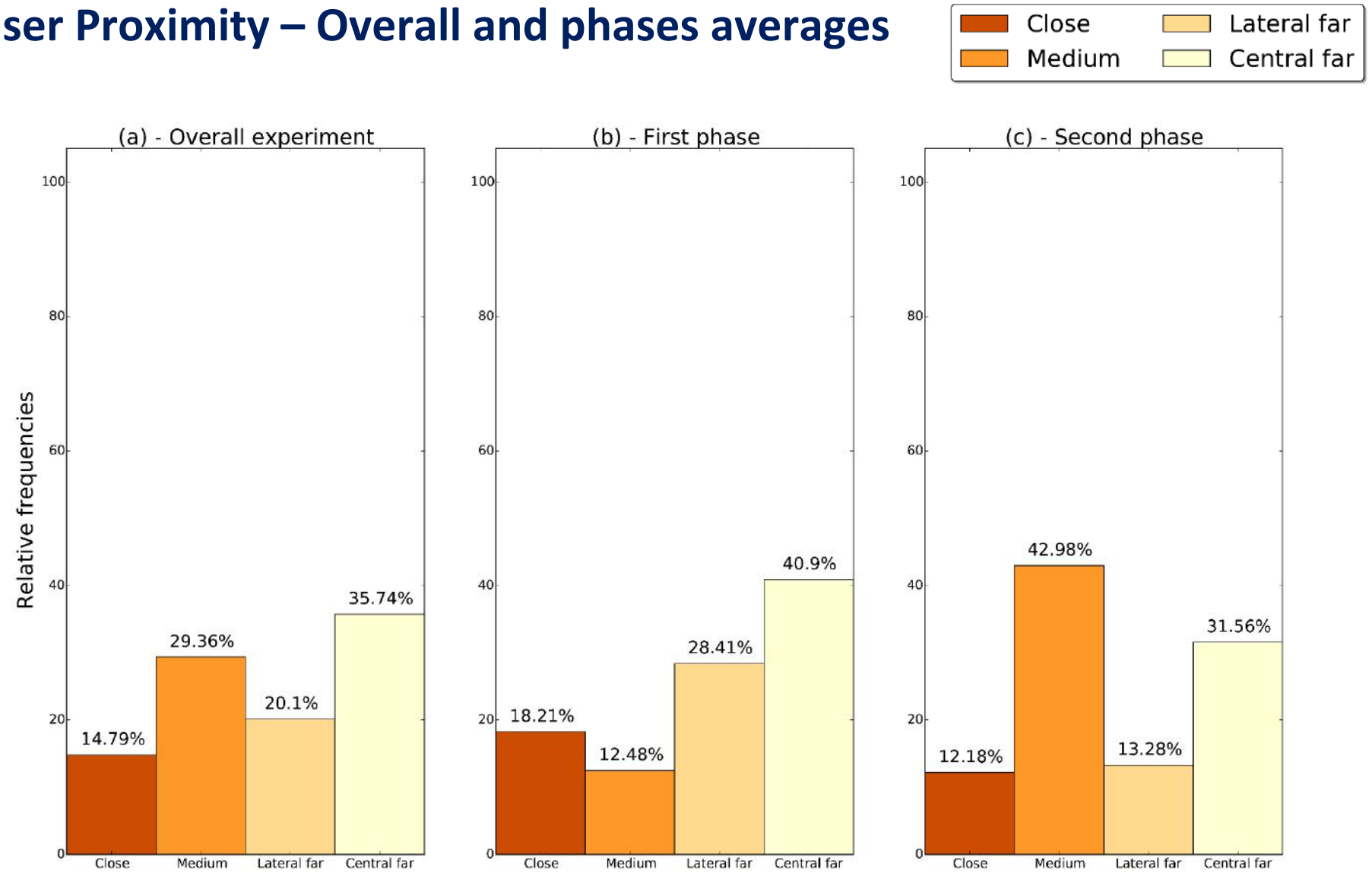
For each user, the **user proximity to the display** was extracted following these four codes that characterize the **display proximity set of codes**:



For all the studied measures, **it is necessary to maintain a state for at least 5 seconds** to keep it valid.

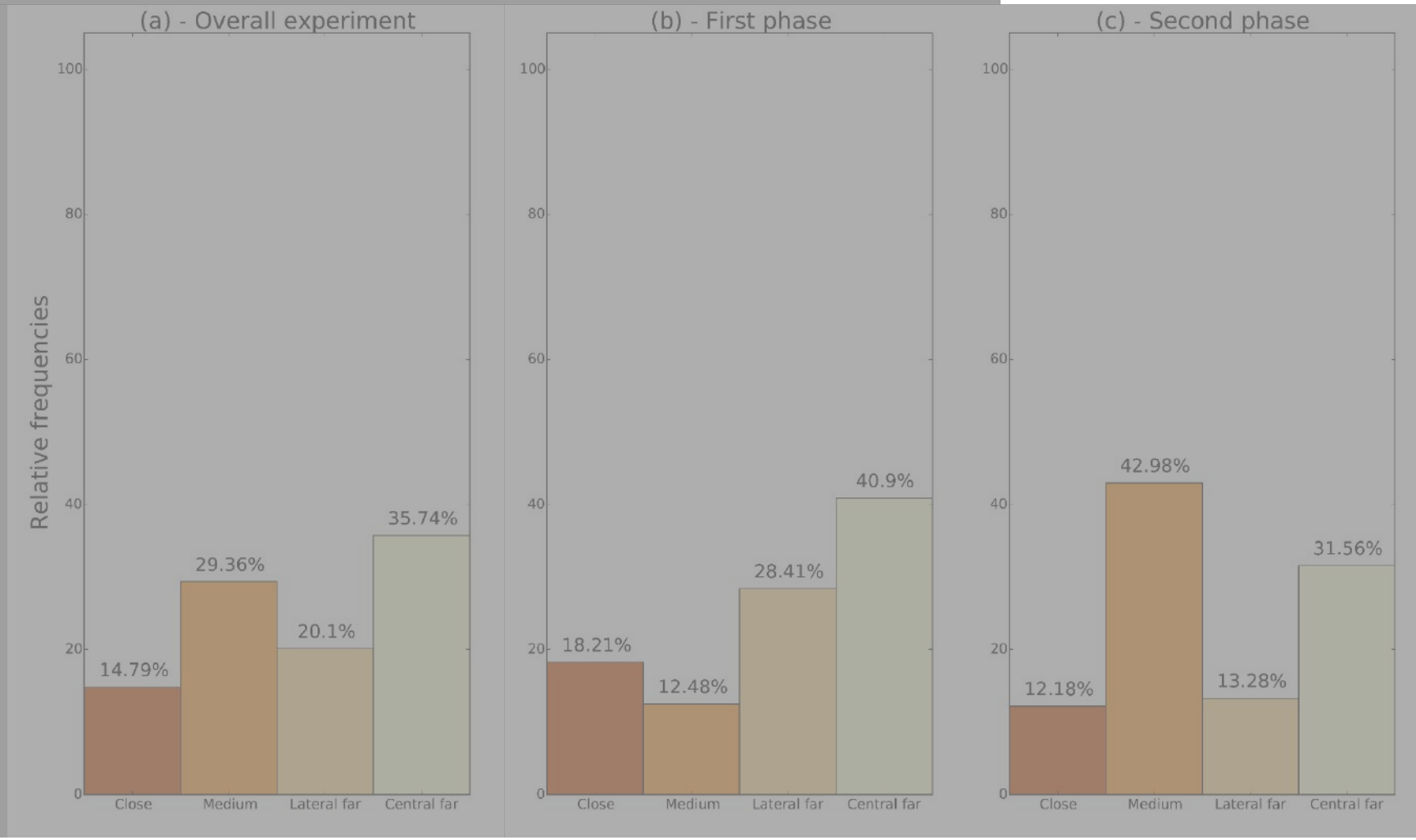
Display proximity analysis (1/2)

User Proximity – Overall and phases averages



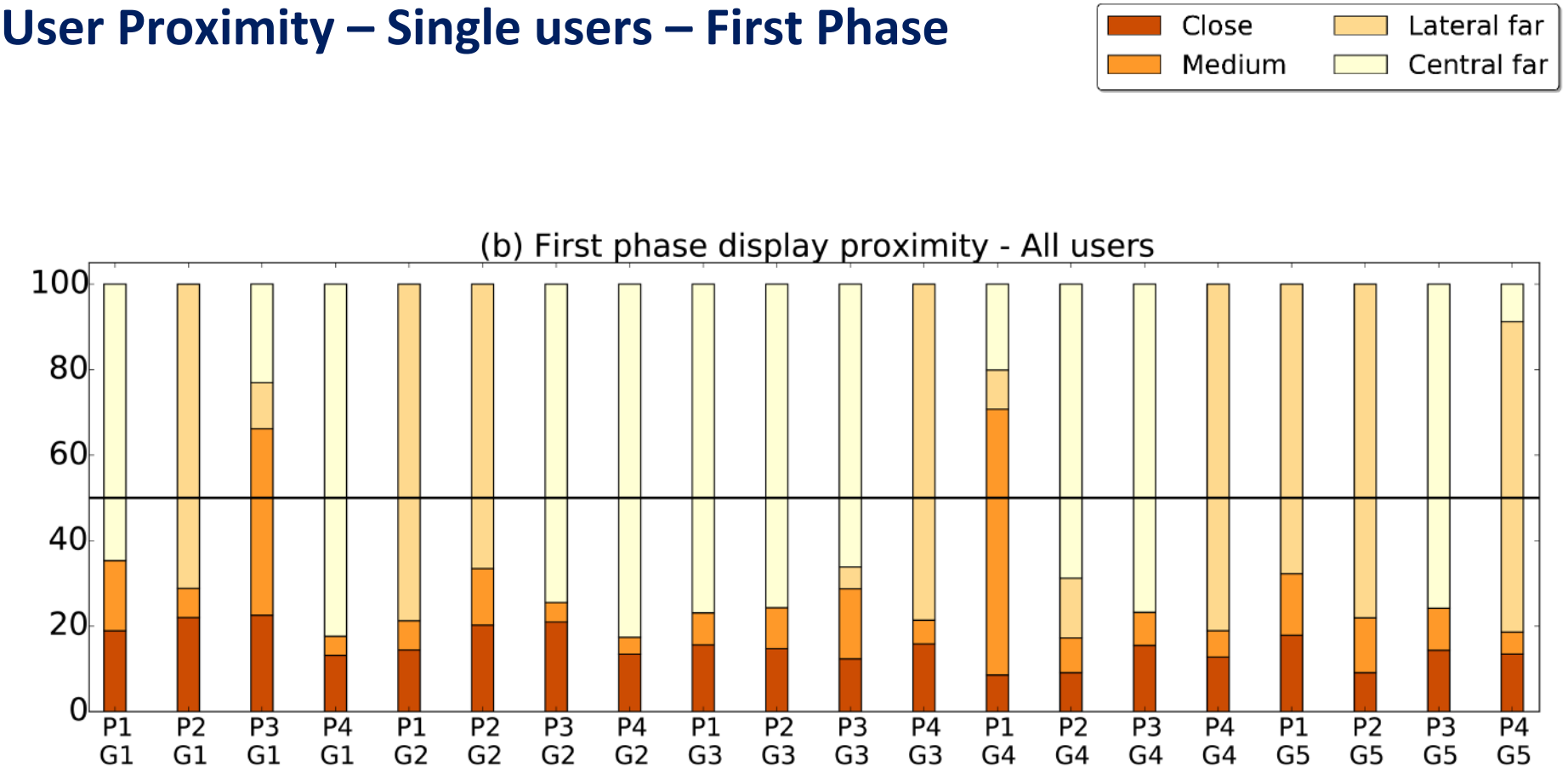
Display proximity analysis (1/2)

User Proximity – Overall and phases averages



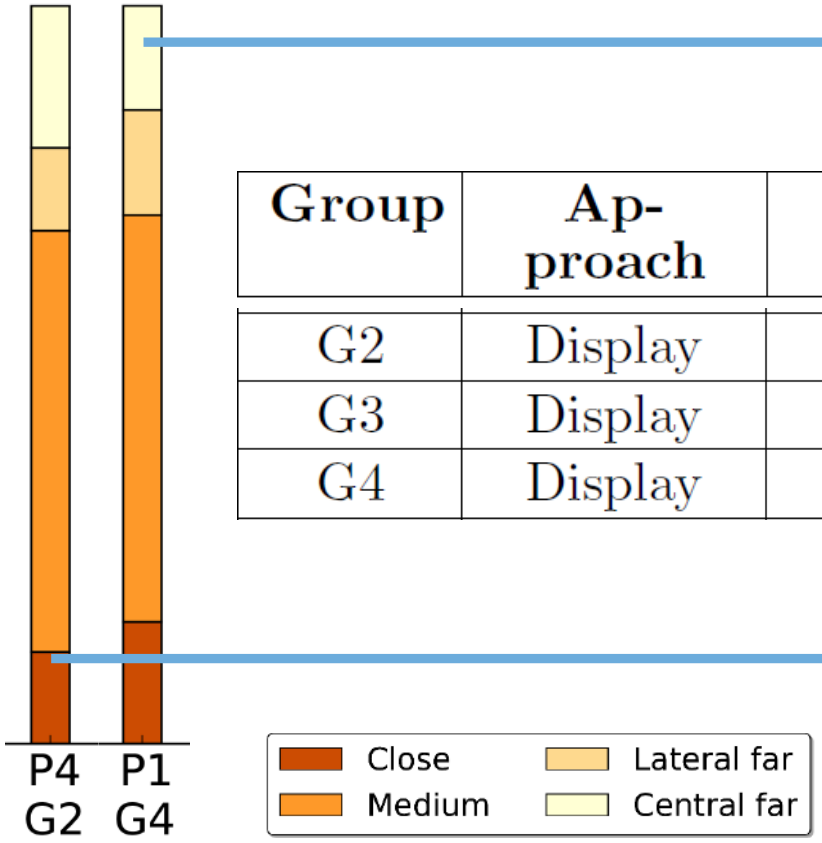
Display proximity analysis (2/2)

User Proximity – Single users – First Phase



Combining score and display proximity

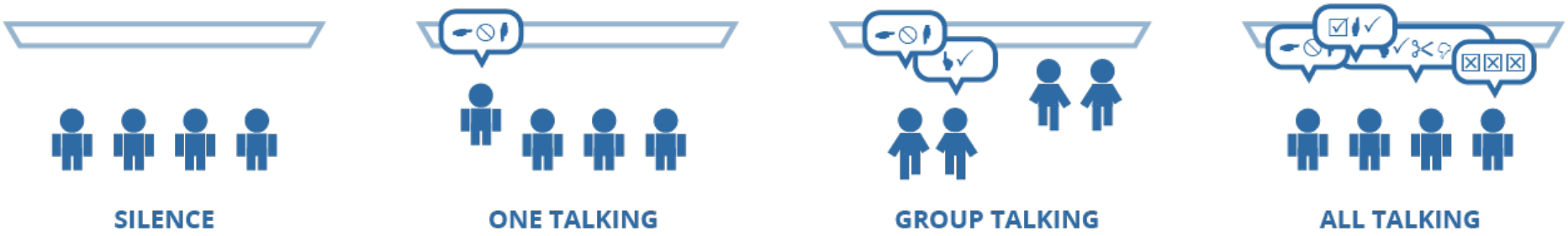
There is an interesting pattern combining the display proximity and the user's score. Users who stayed closer to the display in the first phase got a very low result.



Group	Ap-proach	Overall Score	P1	P2	P3	P4
G2	Display	143	38	38	**39**	28
G3	Display	143	**37**	36	35	35
G4	Display	139	29	**38**	36	36

Verbal communication coding

Verbal communication is divided in **four group codes**:

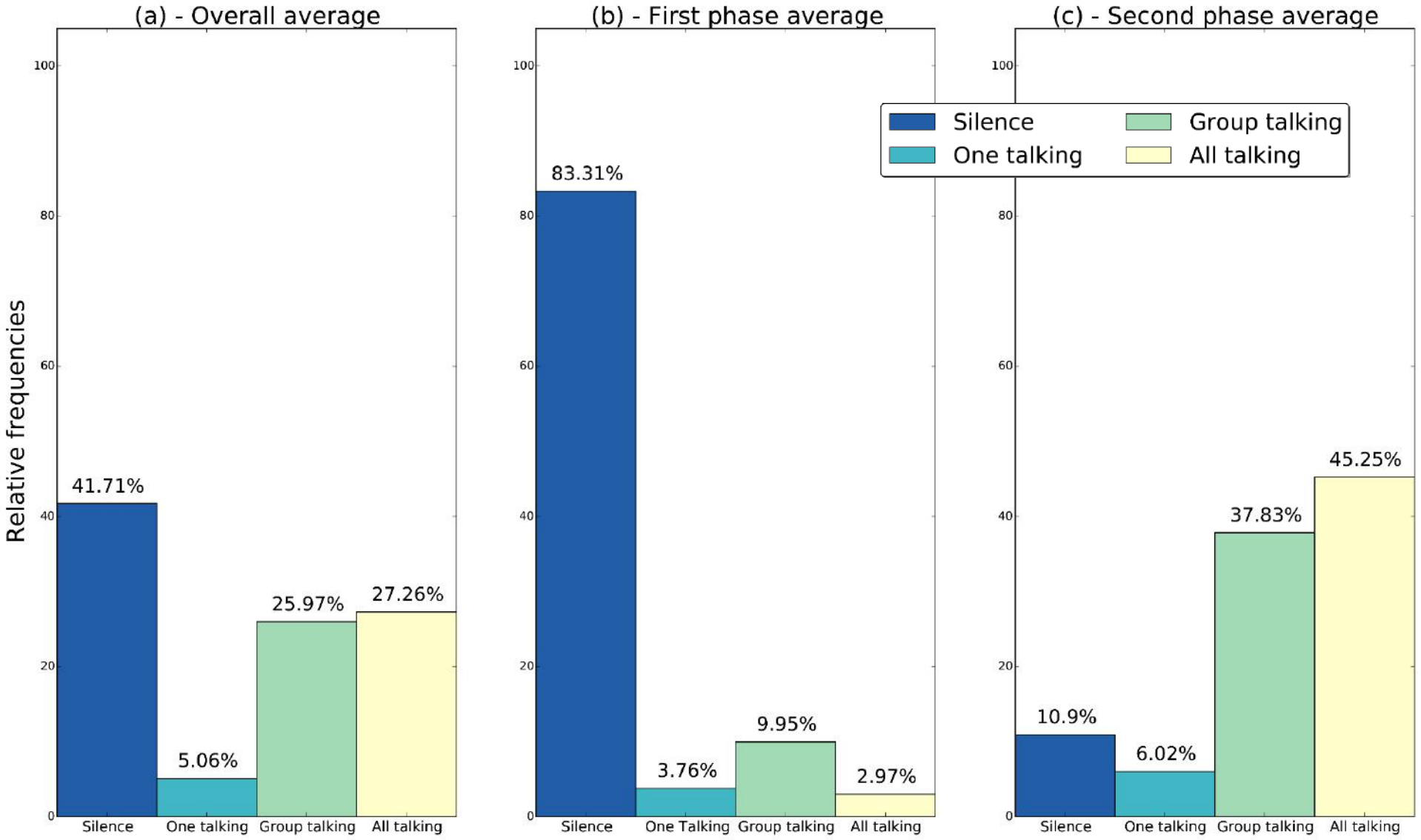


Silence and **One talking** do not identify a form of interaction among users. They identify a **competitive** behavior.

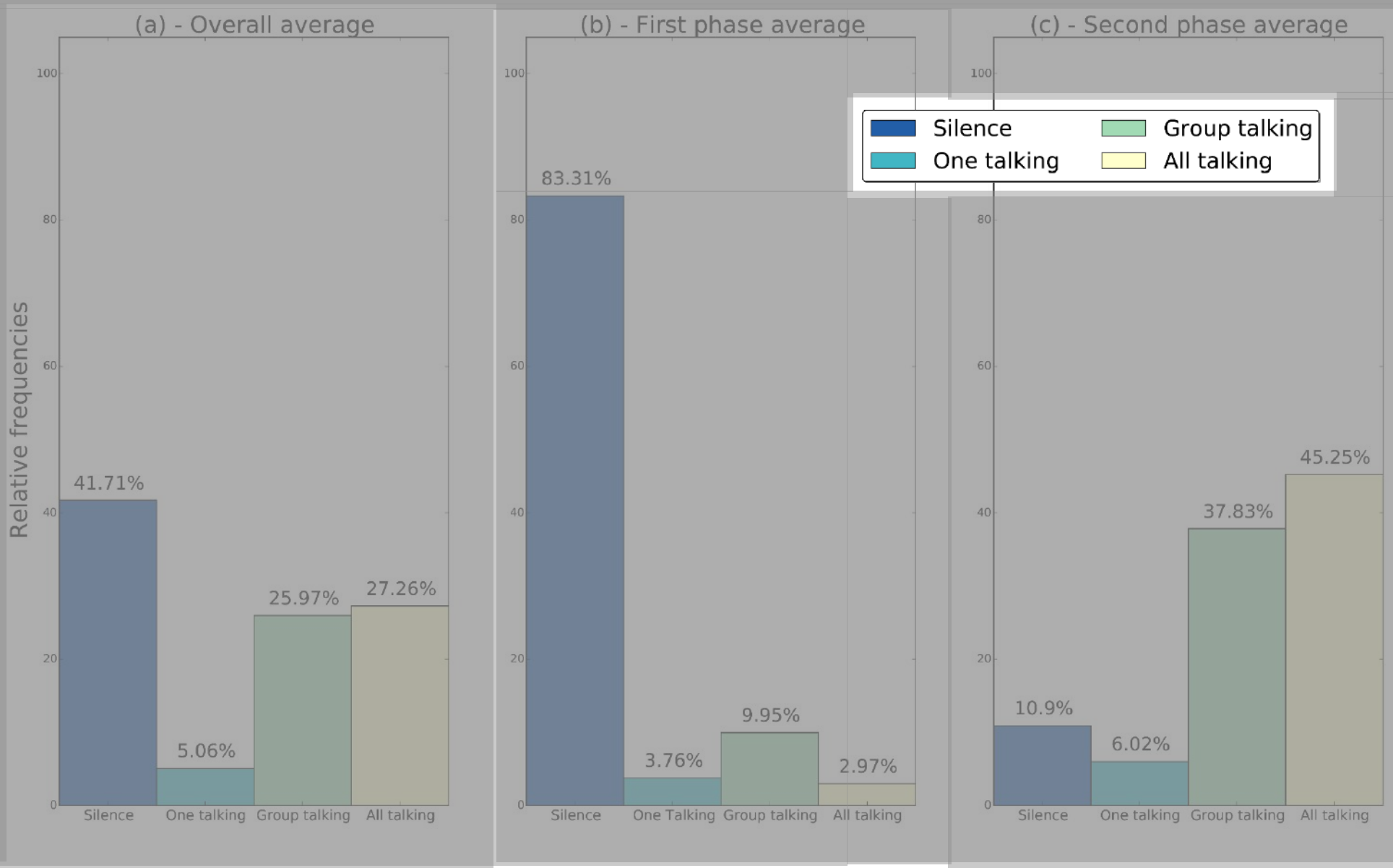
Group and **All talking** identify a form of interaction. The interaction can be:

- **Negotiation**: collaboration or competition;
- **Mutual help**: the users collaborate to find a solution;
- **Other.**

Verbal communication analysis

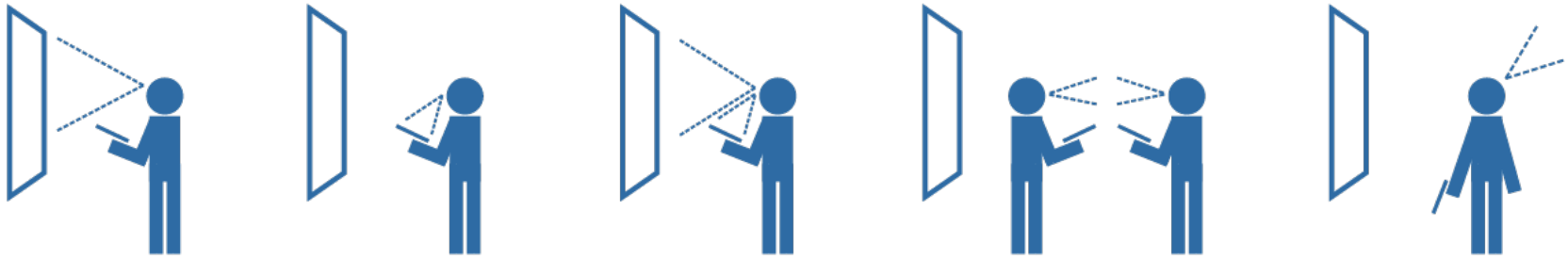


Verbal communication analysis



Visual attention coding

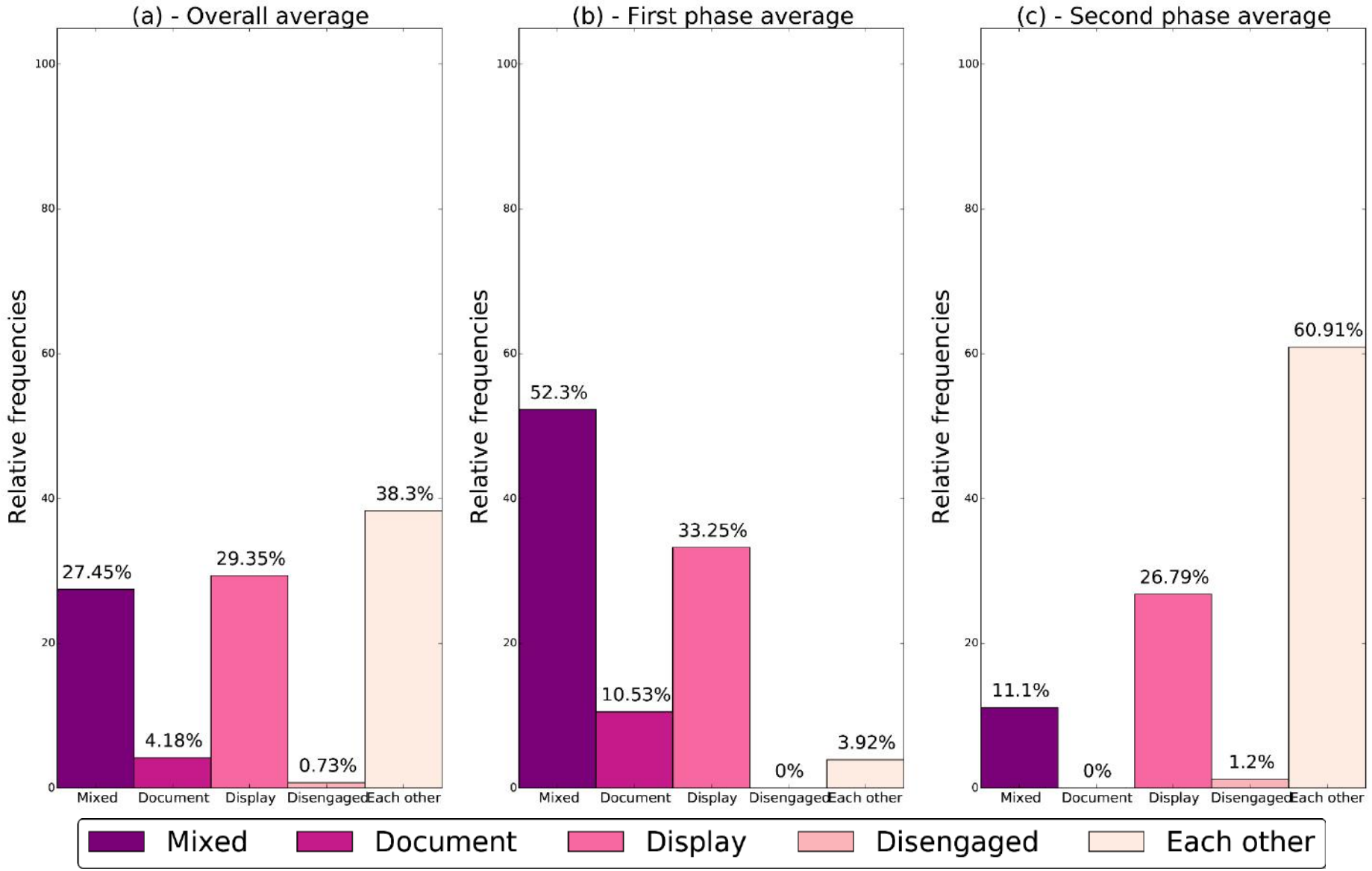
Visual attention is divided in **five group codes**:



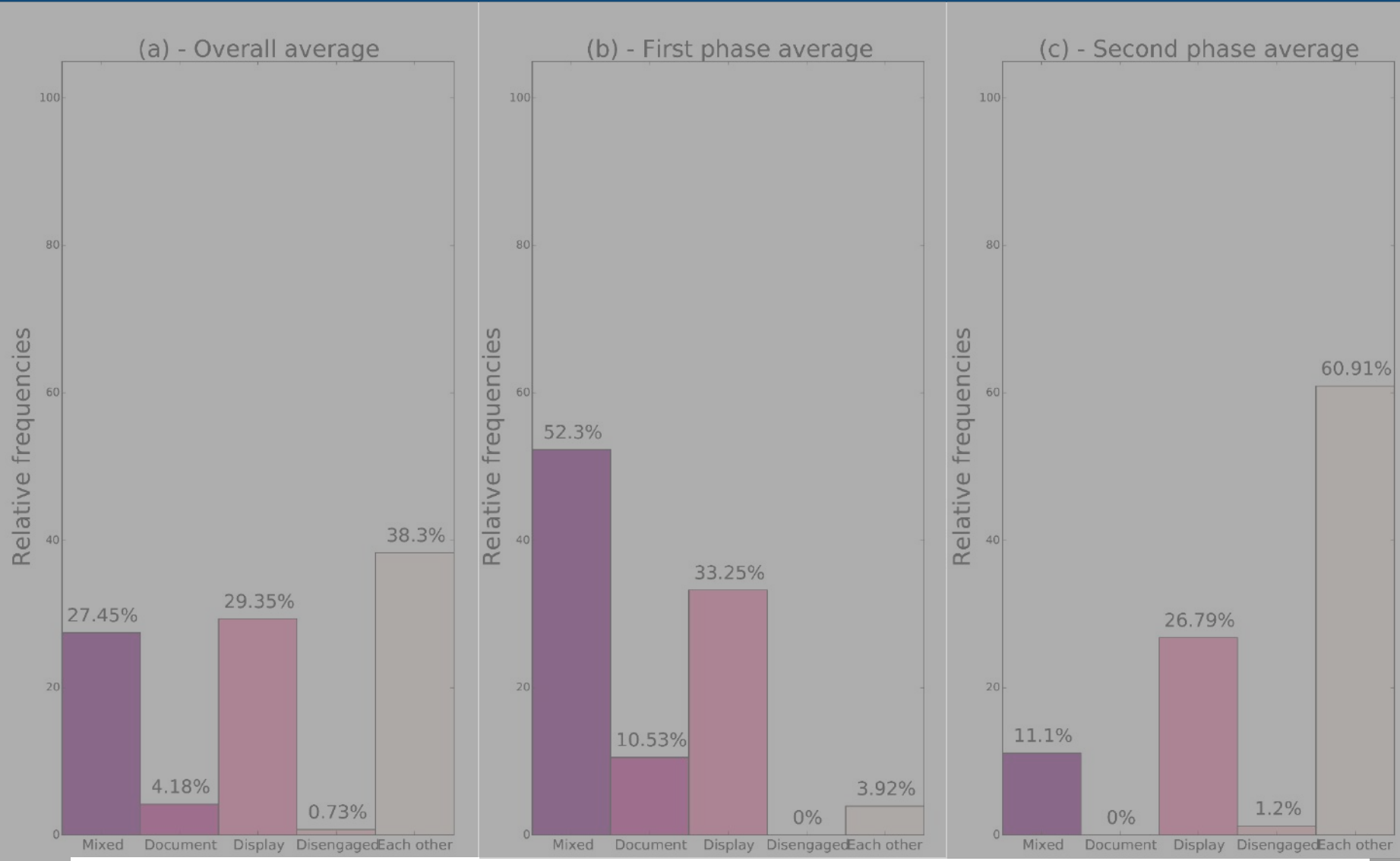
These states do not imply any competitive or collaborative behavior.

However, we will see the importance of this set of codes using a joint analysis with the visual attention and the verbal communication.

Visual attention analysis

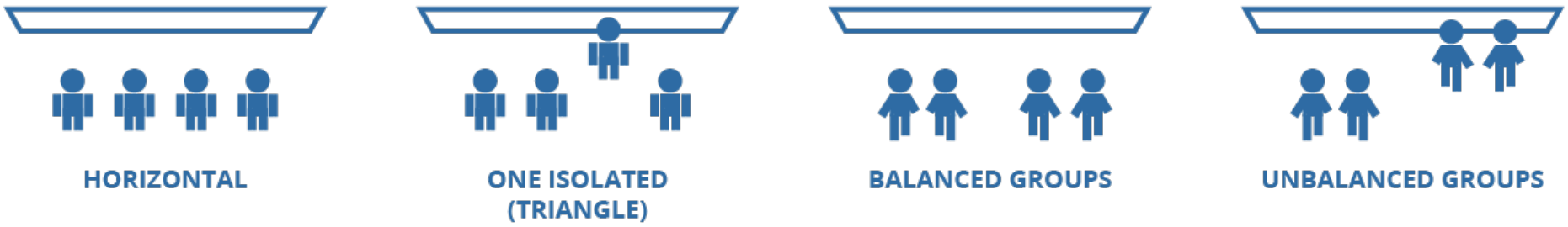


Visual attention analysis



Group shape coding

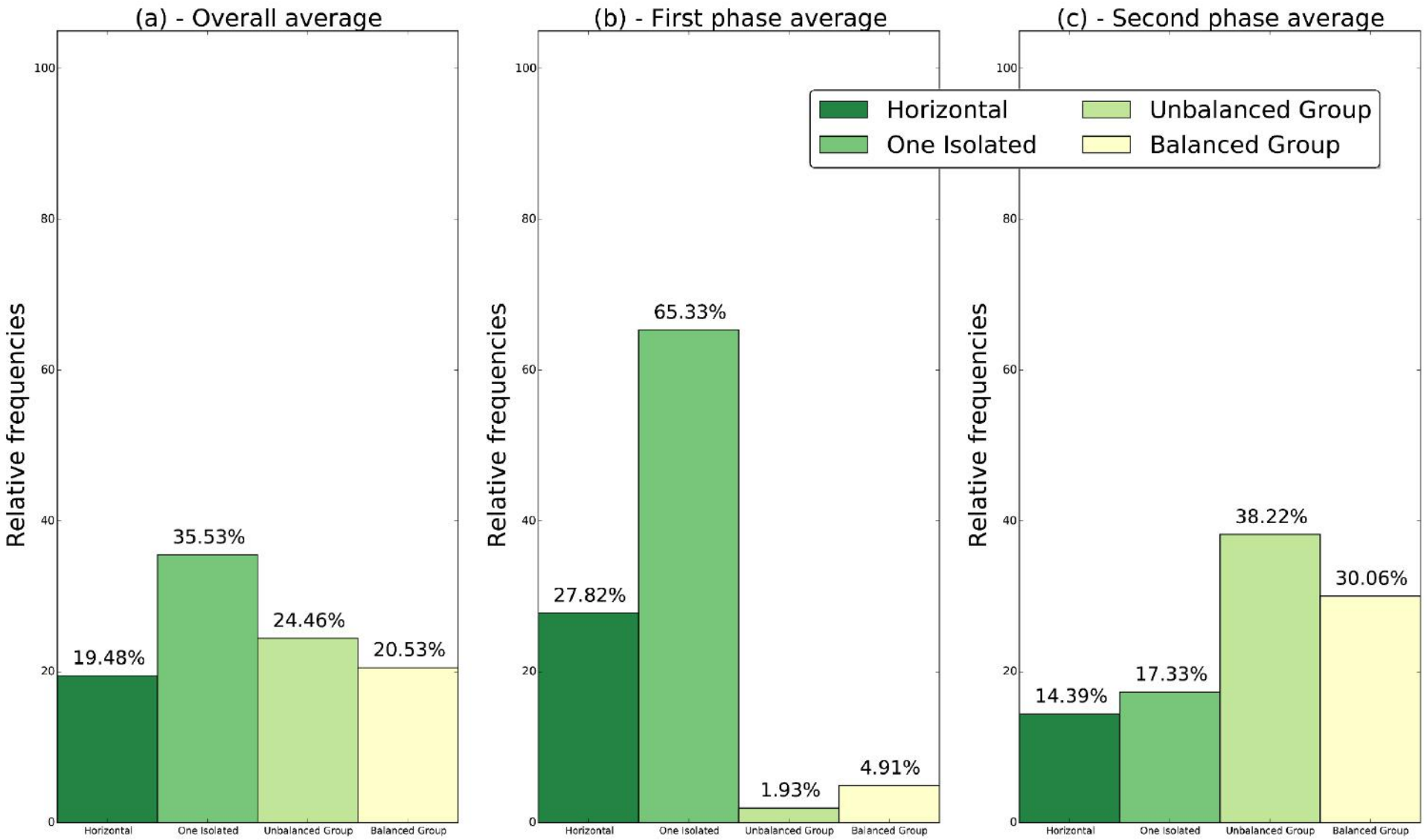
Group shape is divided in **four group codes**:



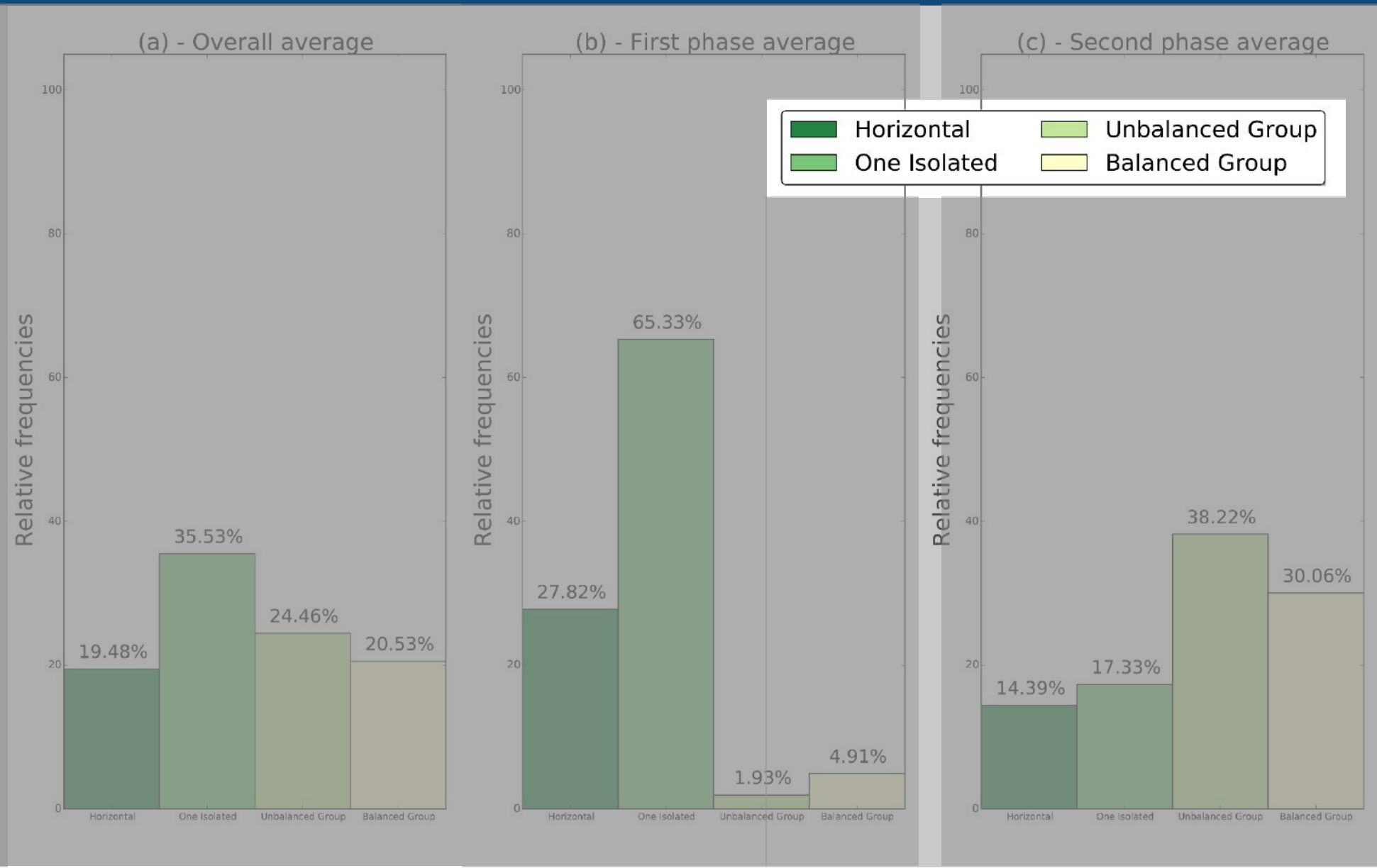
Silence and **triangle** identify a **competitive** behavior.

Group states identify both collaboration and competition (negotiation, mutual help, other).

Group shape analysis

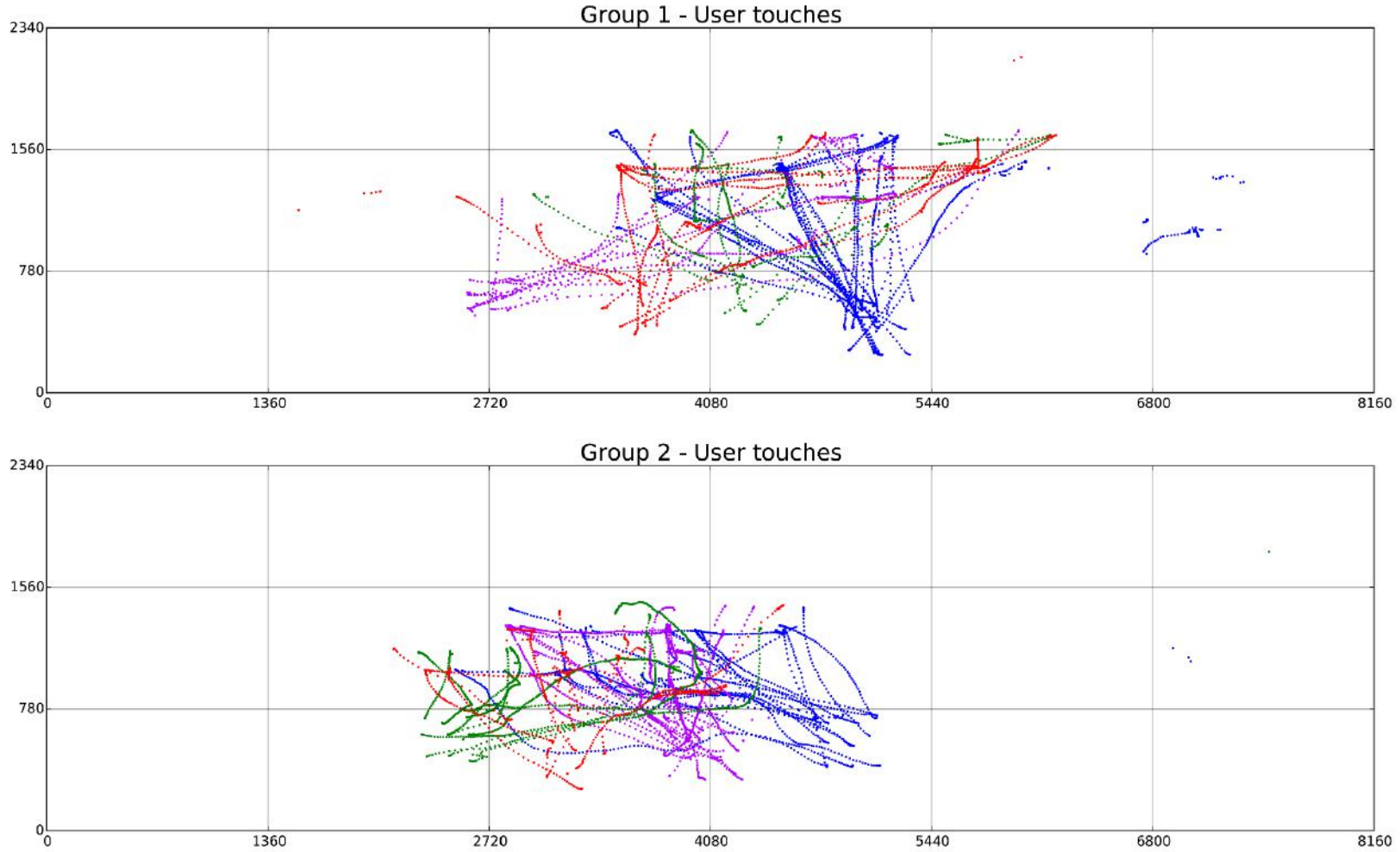


Group shape analysis



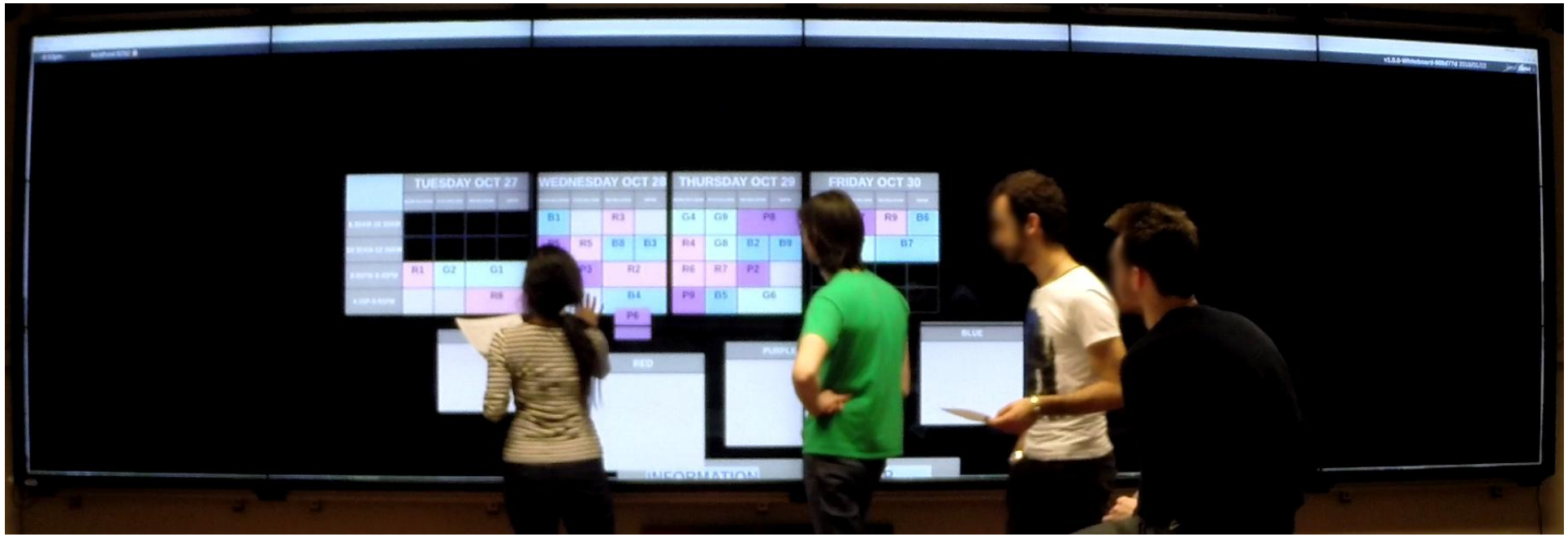
Display usage (1/3)

Each point represents a touch of a particular user.
Touches are mainly distributed within the center of the display.



Display usage (2/3)

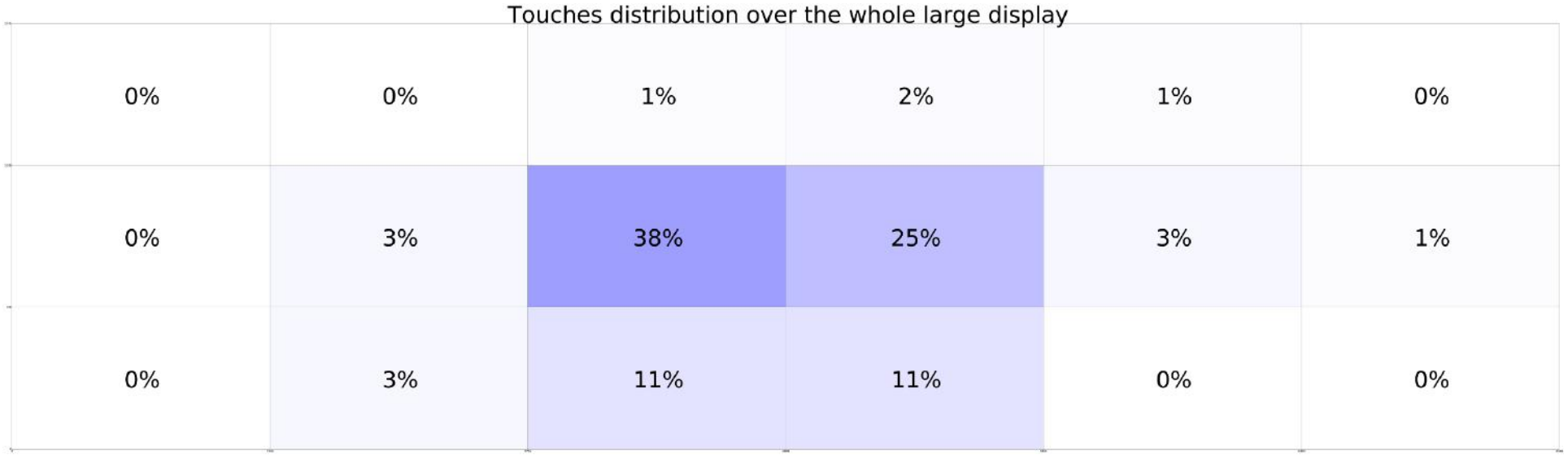
We see that the touches are compatible with a frame of the experiment.



It is interesting to notice how users preferred to use a reduced part of the LVD.

Display usage (3/3)

Users used mainly the four central displays.



The LVD was approximately touched less than 30% of its surface.

Comparison with other studies (1/3)

Unfortunately, most of the studies on LVD are too different from this task. The most similar are:

- **S1**: **Competition** using an LVD with single and multiple mice interaction [1]

  Three users had to create the first page of a newspaper. Each user represents a topic and maximizes his score inserting articles with keywords associated to his topic.

- **S2**: **Collaboration** using an LMVD [2]

  Pairs had to find a hidden plot in a vast catalog of documents and images.

[1] Birnholtz, Jeremy P., et al. "An exploratory study of input configuration and group process in a negotiation task using a large display." Proceedings of the SIGCHI conference on Human factors in computing systems. ACM, 2007.
[2] Jakobsen, Mikkel R., and Kasper Hornbæk. "Up close and personal: Collaborative work on a high-resolution multitouch wall display." ACM Transactions on Computer-Human Interaction (TOCHI) 21.2 (2014): 11.

Comparison with other studies (2/3)

Comparison with S1

- Users used mainly the central part of the display in which a shared central item was present (the same in this study)
- Users felt the competition more when they were free to use the display with the multiple mice condition (this happened less frequently in our study since users felt the competition more in the first phase – turn based)
- The competition was felt less with the increase of time (the same happened in this study)
- Users talked more in occasions of negotiation (the same happened in this study)

Comparison with other studies (3/3)

Comparison with S2

- Users stayed 91% of the time close to the display (15%)
- Users evenly shared the display usage without an explicit negotiation (a similar behavior happened in this study)
- Users used the display simultaneously (contrarily to this study where user preferred to wait for the display to be free)
- Users looked mainly at the display (the same in the first phase where users did not need to interact)
- Display usage was lower than 50% (lower than 30%)
- The main conclusion of S2 is that users are willing to share the display. The same behavior was found in our study.

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Conclusions (1/3)

- There are no differences between the task results using the LMVD or the traditional approach.
- Users largely preferred the usage of the LMVD against the traditional approach.
- Users were not distracted by the presence of the LMVD during the task execution.
- Users stayed in a touch distance to the display for 15% of the time and in a far distance (more than 1 meter) for 45% of the time.
- The display was used only in its central part (excluding the top central part) and for less than 30% of its surface.

Conclusions (2/3)

- Users felt the competitive variable more at the beginning of the task. Then, during the task execution the competition was felt less and users collaborated more.

- When users have to decide their strategy (first phase), they were mostly in silence (83%), were far from the display (70%), in a triangular shape (65%) or in a horizontal shape (28%), and looked mostly at the display and their documents.

- When users have to negotiate (second phase), users were mostly talking in groups and all together (83%), were in an intermediate distance to the display (43%) and far from it (45%), gathered in groups (68%), and looked mostly at each other (61%).

Conclusions (3/3)

This study analyzed **groups of four people** performing a **competitive/ collaborative** task (scheduling session for a scientific conference) using an **LMVD**.

- It largely **described** and **analyzed the human behavior** performing this task under the aspects of **verbal communication**, **visual attention**, **group shape**, **display proximity** and **usage**;

- The collected **data did not communicate any efficiency improvement in the usage of the technological approach** compared to the traditional one, neither in the quality of the results. However, questionnaire outcomes state that **users largely preferred the LMVD**.

Future Works

Regarding the application: Implement the requested features by the users in the Conference Scheduler application.

Regarding the User Study:

- Analyze more groups to make stronger conclusions;
- Focus exclusively on the human behavior neglecting the approach-efficiency analysis;
- Make two alternative studies:
  - Removing the collaborative variable;
  - Having everything on the display, so without physical documents (a more display-interactive study).

Questions?

Joint analysis of measures

A **joint analysis** using **adjusted residuals** is done to understand if some codes are dependent with one another.

Adjusted residuals give a **standardize measure** of the **difference** between the **observed frequency** and the **expected frequency** of a joint event.

When an adjusted residual is higher than 1.96 or lower than -1.96 there is only probability lower than 0.05 that the observation is given by chance.

Joint analysis of verbal communication and visual attention

Red rectangle identify states where users do not interact;
Green rectangle identify states where users interact;

	Silence	One talking	Group Talking	All talking
Mixed	5.88	2.10	-4.22	-5.50
Documents	9.78	-2.91	-5.42	-3.57
Display	-4.47	5.35	3.96	-4.58
Disengaged	5.81	-2.48	-2.22	-2.35
Each other	-10.49	-5.23	4.76	14.53

1. **Mixed** and **documents** states are frequently observed when users are in **silence**;
2. Users generally talk in **group** or **all together** looking at **each other**;
3. Users **disengaged** are often in **silence**;
4. When the users are looking at the **display, one** user is talking or they are talking in a **group**.

Joint analysis of verbal communication and group shape

Red rectangle identify states where users do not interact;
Green rectangle identify states where users interact;

	Horizontal	One isolated	Unbalanced group	Balanced group
Silence	3.70	2.23	-3.22	-4.78
One talking	1.98	3.52	-3.41	-3.98
Group talking	-3.75	-2.81	4.26	4.60
All talking	-3.59	-4.25	4.08	6.46

1. **Horizontal-silence** and **one talking-one isolated** often happen together;
2. **Group** states are likely to happen together.

Joint analysis of visual attention and group shape

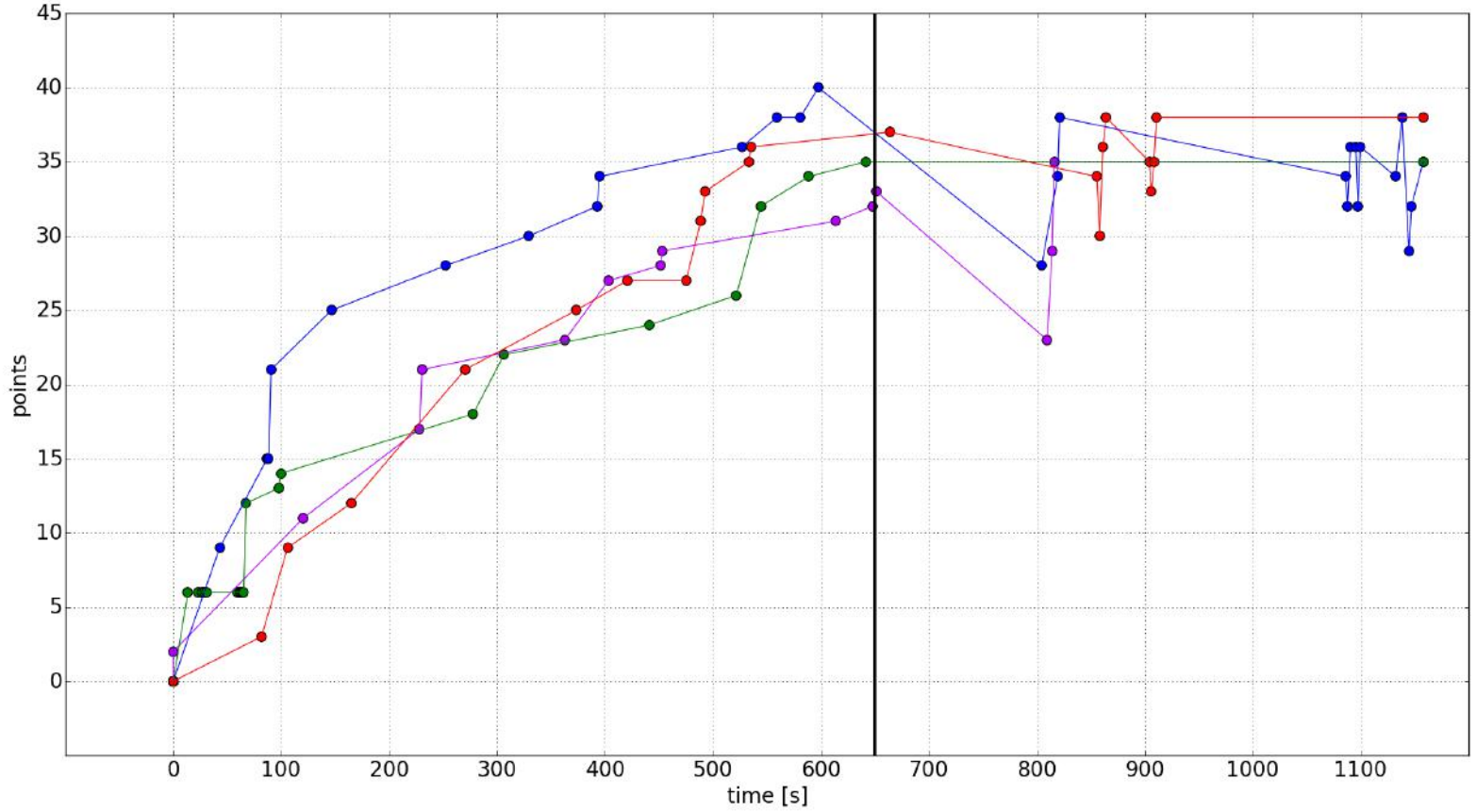
Red rectangle identify states where users do not interact;
Green rectangle identify states where users interact;

	Horizontal	One Isolated	Unbalanced groups	Balanced groups
Mixed	6.01	4.49	-5.93	-5.89
Documents	2.68	1.98	-2.11	-3.11
Display	-3.25	-1.90	-1.87	7.48
Disengaged	-2.21	-1.75	5.27	-0.71
Each other	-4.94	-4.10	7.53	2.75

1. **Mixed** state is assumed when users are in an **horizontal** or **triangle** state. It is infrequent to observe this state with the **group** shapes;
2. **Group** shape states happen often when users look at **each other.**
3. When users are **disengaged**, they are more frequently in an **unbalanced group**;
4. Users look at the **display** for more than 5 seconds when they are in **a balanced group**.

Efficiency analysis – Personal result (1/2)

Approaches efficiency analysis – Personal results (Traditional)



Efficiency analysis – Personal result (2/2)

Approaches efficiency analysis – Personal results (Display)