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Study on generic tangible objects used to collaborate remotely on RFID tabletops

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Abstract

Having the tools to work remotely with other people is one of the ambitions of people who work in a group context. In fact they have to move and to link their team-work in order to collaborate on one or several tasks. This paper describes a study on an innovative system designed to support remote collaborative applications on tabletops with tangible interaction. We propose a set of generic tangible objects. They model a set of collaborative styles which are possible between tabletop users. Our goal is to study the usability of and satisfaction with such objects that provide remote collaboration among users of interactive tabletops for tangible interaction. An application adapted to remote collaboration was tested in the laboratory with adult participants. Twelve test groups, each composed of three participants, tested a distributed application for the learning and recognition of colors. Our analysis, supported by observations, log file analysis and questionnaires, focuses on whether the use of generic objects to collaborate remotely is easy and understandable for users. It also considers user satisfaction when using the distributed tabletop with tangible objects.

Keywords: Tangible interaction; tabletop; remote collaboration; tangiget; RFID.

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1. Introduction

The emergence of new interactive surfaces, especially interactive tabletops, has helped to provide solutions to typical problems encountered by users of conventional WIMP media types: a limited number of co-located people working together; the limited size of the documents to be processed; the limited quantity of information displayed simultaneously on the support. Among the advantages of an interactive tabletop, the following should be mentioned:

- The opportunity to work on large-size documents without the need to proceed part by part, due to the width of the display surface.
- A large area around which more than two people can be gathered to work together or independently.
- The possibility of having a common workspace on the tabletop for all users, or of each having his/her own workspace on the same tabletop [1].
- The possibility of working with tolerable levels of precision (unlike a limited size screen that requires high precision pointing).

Such advantages have encouraged researchers to design and develop applications with collaborative elements to be performed around the same surface (see [2-7]). Other studies have tried to go further by exploiting the concept of remote collaboration via at least two interactive surfaces. The works of [8-11] can be cited as examples. The main purpose of such research projects is to keep the spirit of collaboration present in co-located teamwork by extending it to remote collaborations in order to avoid people who want to work together on an application or a document having to move in order to do so.

However, this type of collaboration, especially via remote tabletops, has resulted in new collaborative difficulties; some works have dealt with the aspects of remote collaboration in such situations of interaction: in [9] a solution for remote face to face collaboration using a video conferencing system was proposed; in [12] the basic principles for the implementation of a context model supporting the management of remote collaboration on tabletops were put forward; in [13] a user interface distribution strategy in a context of collaboration between several people via interactive tabletops was suggested.

The concept of weaving computers and technology into the fabric of our physical world has become the subject of several research projects. In fact, ubiquitous computing environments opt for the use of conventional and real physical objects to make human-computer interaction create a natural interaction on an almost subconscious level. Several sectors of activity are increasingly interested in this modality of interaction.

Generally speaking, this article contributes to the design and evaluation of multimodal UI implicating virtual and tangible objects (tangible is in the sense of Ishii and Ullmer [14]) in collaborative contexts. Indeed this work uses interactive tabletops associated with tangible objects; these objects can be detected and coupled with virtual displays on the screen of each tabletop. Tangible objects, equipped with RFID tags, are placed and moved on each tabletop. The tabletops detect their position and act consequently. This interaction is tangible as well as virtual; indeed, several virtual areas located on the surface of each tabletop are used. The feature of such an interactive platform is that it provides natural interaction like on classical physical tables. Tangible objects can be overlapped, dedicated to certain users or shared. They are detected by the tabletop with a precision of 0.79 inches.

More precisely, this paper contributes to the collaboration between people located at remote tabletops, by using tangible objects. For that aim, we propose a set of generic objects called tangigets to facilitate remote collaboration in accordance with so-called collaboration styles initially proposed in the literature. These generic tangible objects complement specific tangible objects dedicated to the application. Tangigets are intended for different categories of well-targeted actions and are designed to make collaboration and communication possible via the tabletops.

Section 2 aims to present some research activities that deal with the concept of collaboration between users through interactive tabletops. It also aims to present the notion of collaboration and its different formats through a set of collaborative styles proposed by researchers, as well as a set of generic objects to support communications and exchanges through the tabletops

In section 3, our contribution is explained. It is a concretization of the collaboration styles identified by [15] via a set of generic objects introduced in [16] in order to establish a remote collaboration between users of interactive tabletops with tangible interaction.

Section 4 is dedicated to a case study. We propose a distributed system over two interactive tabletops accompanied by a set of tangible objects (tangigets & specific objects). The tangigets were designed to facilitate collaboration between the users of these two tabletops. The application was tested by several groups. The test procedure is presented in this section.

In Section 5, we analyze the data resulting from the tests. There are two types of results: subjective results obtained through the analysis of questionnaires, and objective results revealed by the log files.

In Section 6, the results are discussed.

2. Related work

Several studies have been conducted in the field of collaboration which try to take advantage of evolutions in the technologies offered and to facilitate interventions that require a lot of effort and travelling [17] [18].

Each study has a different set of particularities according to the needs expressed for the proposed system. We focus on representative studies concerning tabletops as interaction support.

Esenther et al. [19] established the RemoteDT system. This system operates on the one hand on the DiamondTouch tabletop around which people collaborate, and on the other hand on a PC and a smartphone used by another user working remotely with the tabletop users. This first proposal allowed the authors to study the usefulness and feasibility of this type of remote collaboration.

A proposal for collaboration between two interactive tabletops is found in the work of Yamashita and al. [20]; these authors tried to simulate the physical presence of remote collaborators by real time video projections of what was going on remotely on supports around each tabletop. It was also possible to interact, in real time, with the behavior of the application running on interconnected interactive tabletops.

In parallel, in [9], Minatani et al. proposed a simulation of the real presence of the remote user through a 3D simulation of their instantaneous position.

Cuendet et al. [21] proposed the Tapacarp system, which is a collaborative application on an interactive tabletop. It aims to help carpenters to cut beams and to assemble them. This application presents a solution in a learning framework for co-located users. The work does not focus on the possibilities of performing this activity remotely via interactive tabletops with tangible interaction.

Melchior, in [22], discussed the notion of collaboration via the use of Distributed User Interfaces (DUI). He was particularly focused on the interest of a complete method for DUI design; he studied which models, languages, development approaches and supporting software could be defined and implemented. For this author, distribution primitives have to be defined before any other step.

Sluis et al. also featured a collaborative interactive application on an interactive tabletop. This application allows children to perform collaborative activities around a tabletop. Read-It is a multimodal activity that focuses on co-localized collaboration between children [23].

Table 1 summarizes the representative works mentioned above in the area of collaboration by classifying them according to the type of collaboration adopted (remote or co-located), the interaction platform used by every cited system, as well as the modality of the interaction surface used.

We note that most of the research activities studied focus mainly on the use of interactive surfaces with tactile interaction to result in remote collaboration.

The analysis of the cited works shows that none of these works really deals with the concept of remote collaboration based on the distributed user interfaces of the interactive tabletops. In this work, we are interested in achieving a reliable remote collaboration between users of interactive tabletops with purely tangible interaction, while using the features offered by these tabletops, as well as a set of objects that will be the main elements in this collaboration.

In order to ensure reliable collaboration, the researchers opted to classify possible collaborative situations using digital platforms. Some of them concern co-localized collaboration, others concern remote collaboration

Tuddenham and Robinson [24] highlight the growing interest in tabletops with user interfaces that enable remote collaboration, while providing shared workspaces. This approach assumes that these remote tabletops offer the same beneficial work practices as in a co-located collaboration around the same tabletop interface [24]. For this, they exploit the notion of coupling styles suggested by Tang et al [25] in their work to respond to the features of interactive tabletops. The concept presented in [25] identifies a set of possible styles of collaboration between users as a part of work on a given item in a particular problem or situation.

Table.1 projection of previous works on the main axes of our work

System		Esenther et al. [19]	Yamashita et al. [20]	Minatani et al. [9]	Cuendet et al. [21]	Melchior [22]	Sluis et al. [23]
Collaboration type	Co-located	-	-	-	✓	-	✓
	Remote	✓	✓	✓	-	✓	-
Interaction platform	Tabletop	✓	✓	✓	✓	-	✓
	Other	-	multiple cameras, screens, and speakers	Mixed reality	-	-	-
Modality of interaction		tactile	tangible	tangible	tangible		tangible
Distributed interface		✓	✓	-	-	✓	-

The so-called coupling styles used as the reference in this article [25] were:

- (SPSA): (Same problem same area): Collaborators are actively working together.
- (VE): (View engaged: One working, another viewing in an engaged manner
- (SPDA): (Same problem, different area): Collaborators are working simultaneously on the same sub-problem, but are focused on different parts of the table.
- [V]: (View: One working, another viewing): One collaborator is working on the task, and the other is watching, but is not sufficiently involved to help or offer suggestions.
- [D]: (Disengaged: One working, another disengaged): One collaborator is completely disengaged from the task, not paying any attention to the task or partner.
- [DP]: (Different problems): Collaborators are working completely independently on separate sub-problems at the same time. Each person's interactions with the workspace are not related to the other in any way.

To confirm their idea, Tang et al. [25] based their work on the idea of simulating the shadow of the users' hands on the local tabletop; it is thus possible to show the actions performed by the remote user on objects on the other tabletop and to provide the user with an overview of changes in the position of objects.

In order to extend this proposal to cover collaboration on interactive tabletops, Isenberg et al. [15] intended to list all possible collaboration styles on interactive tabletops. Eight different styles were identified. Four are more specific to co-located collaboration. The other styles may be applied more in remote collaboration.

These styles are defined in [15], and illustrated in Fig. 1, as follows:

DISC: *Active DISCUSSION about the data or task.* Limited system interaction (e.g., pointing to items or scrolling in documents)

VE: *View Engaged.* One person is actively working; the other watches and engages in conversation and comments on the observed activities, but does not interact with the system

SV: *Sharing of the Same View of an artefact or data view.* For instance, users either look at the same document or the same search result list together at the same time

SIDV: *Sharing of the Same Information but using Different Views of the data.* Users, for example, read the same document but using their own copies (views) of the document

SSP: *Work is shared to solve the Same Specific Problem.* Both users use different artifacts from a shared set. For example, they query the system for some data results, then divide the work and each person reads one half of the results

SGP: *Work on the Same General Problem but from different starting points.* For example, both users search the sets of available artifacts to find information about something but start from different searches and consider different sets of artifacts

DP: *Work on Different Problems, and hence different aspects of the task.* For example, one person is interested in searching for information about a certain topic, while the other searches for events around a totally different topic

D: *Disengaged.* One person is actively working; the other is watching passively or is fully disengaged from the task.

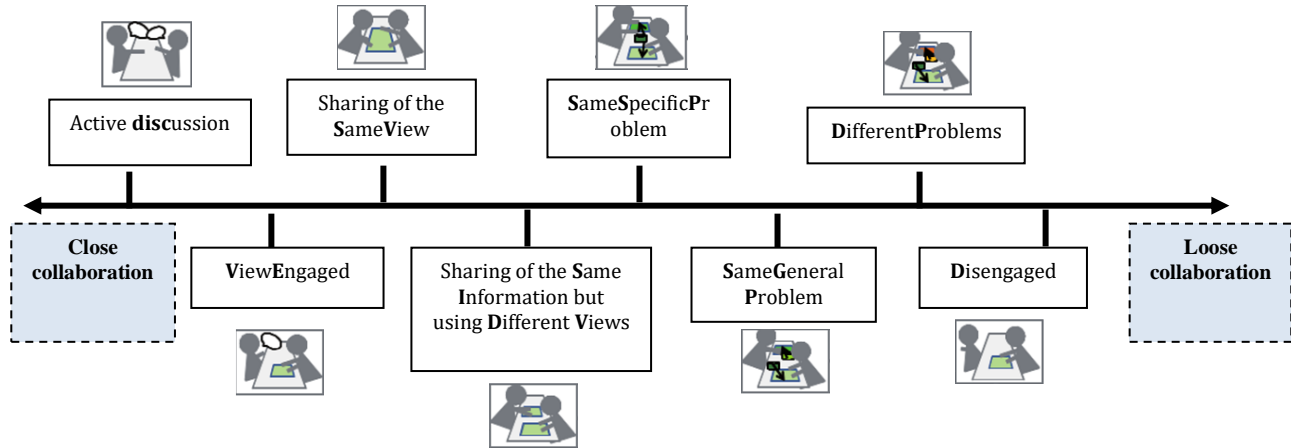


Fig 1. Collaborative styles proposed by [15]

The differences between the work of Isenberg et al. [15] and that of Tang et al. [25] are the following: the former considers more collaboration styles (two more); Isenberg and her colleagues have proposed to organize these styles according to one axis, from the styles applied the most frequently concerning close collaboration to the styles applied the most concerning remote collaboration (no global organization of styles in the second paper).

In order to ensure communication between users of interactive tabletops with tangible interaction, principles of generic tangible objects were proposed in [16] and [26]; these objects are called tangigets (tangible objects), providing a set of interactive features on the tabletop. Based on Fishkin's definition of tangible objects "to use their hands to manipulate some physical object(s) via physical gestures; a computer system detects this, alters its state, and gives feedback accordingly" [27], the tangigets are tangible objects that have different generic functions; the functions taken into account in this paper concern collaboration styles (in the sense of Isenberg et al. [15]). These features mainly cover management application and remote collaboration with other tabletops running the same application.

Lepreux et al. [16] confirm that these objects have a specific feature in that they provide a set of generic fundamental functions or tasks for individual work and group work. These generic objects can be used in several applications: they do not concern a specific part of an application. For instance, a specific tangible object representing a traffic sign in a road traffic simulator is not generic and can be called business object; Figure 4 shows business objects which are dedicated to the application described in the case study section.

Tangigets are spread across 6 categories defined as follows:

Control Objects of the Application: to control the execution course of the applications, e.g. Start, Stop, BeginTask, StopTask, Save, Print...

Context Objects of the Application: to request help to configure preferences.

Control Objects of the User Interface: to manage the UI of the tabletop according to different goals, e.g. Identification (named Me); Zoom; focus...

Communication Objects: to communicate with all or some of the users, e.g. Connect, Disconnect, Absent...

Coordination Objects: to manage the tasks between partners, e.g. ShareTask, sendMessage, RequestCollaboration...

Management Objects: to associate functionalities and physical objects, e.g. CreateVirtual, CreateTangible, DeleteVirtual, DeleteTangible Associate-TangibleWithVirtualObject, and DisassociateTangibleObject.

Our work is based on the main principles developed in these last works, in order to exploit these tangigets further and test their potential in practical terms, as part of remote collaboration between different users of interactive tabletops with tangible interaction. Our main goal is to present all the collaborative situations presented in the work of Isenberg et al. [15] through these generic objects in a remote collaborative framework via an interactive table with tangible interaction.

3. Proposition

Working in groups requires collaboration between different members of the same team and/or with members of other groups. Different collaborators can deal with problems in common as they can handle issues which are separate but concern the same generic collaborative subject. These forms of collaboration should provide flexibility and freedom of use of the application in order to better solve the problems treated and schedule tests and other work in common.

This section is structured in three parts. The first one focuses on the collaborative styles. The second one treats the needs of generic tangible objects. Finally, the third part presents the main functions which allow collaborative styles to be supported with some tangigets.

3.1. Collaborative styles

Isenberg et al. [15] proposed a set of collaborative styles that allows all users to work in groups and share information, in a close way or remote way. This work is presented in the related work section. Our main idea is to apply the different styles of collaboration identified by these authors to provide a collaborative application designed for interactive tabletops with tangible objects in the case of remote collaboration. In Fig. 2, for each style, we propose an illustration of interaction between two tabletops. Tangible objects are treated in the following section.

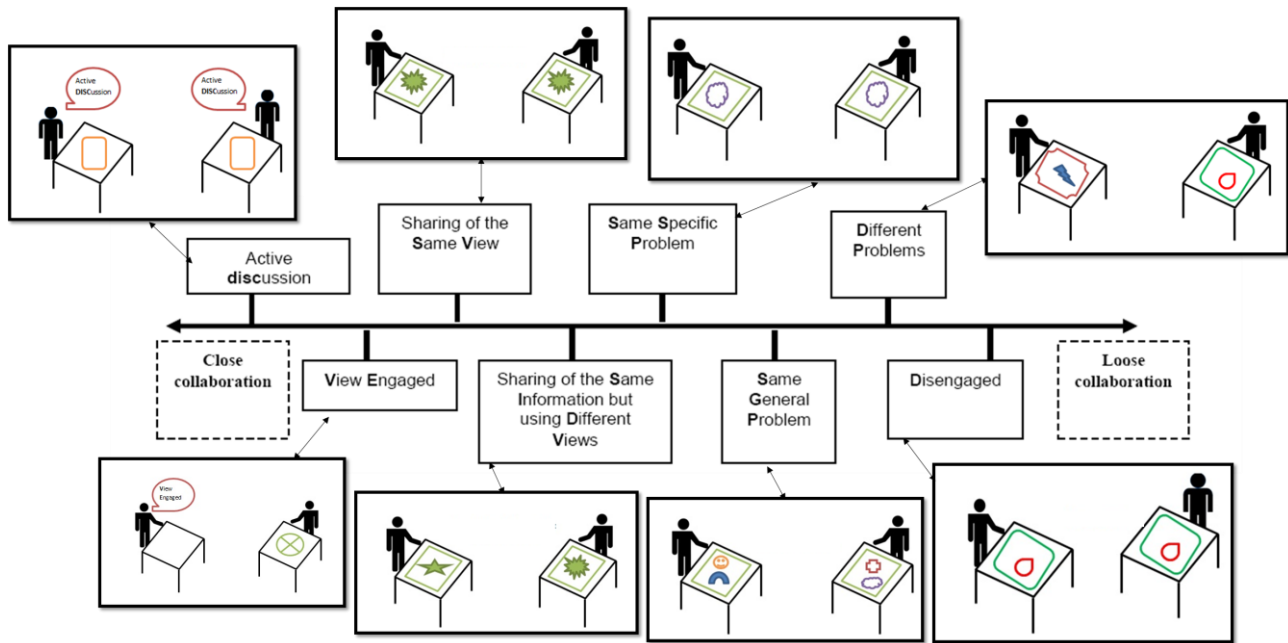


Fig 2. Collaborative styles proposed by [15] illustrated with two remote interactive tabletops

3.2. Generic tangible objects

In order to find a collaborative medium that can materialize our idea, we define generic tangible items proposed in Lepreux et al. [16]; these objects have a specific feature in that they provide a set of generic fundamental functions or tasks for individual work and group work.

We aim to achieve collaboration with interconnected interactive tabletops through tangigets (for any style), while ensuring reliable communication between the different users of the system.

The tangigets are intended to cover all types of tangible generic object originally presented in [16].

First, we crossed the eight collaboration styles with the six categories of tangigets in Table 2 to see what useful features could be found for generic objects (tangigets). The functioning of these proposed tangigets is inspired by the logic of collaborative work concepts. We use a set of basic concepts such as task assignment, mutual assistance between members of the same team (help request /offer of help), the declaration of the end of a personal task or the end of the collaborative activity, and so on. For representative (not exhaustive) purposes, the goal was to offer at least one tangiget per collaboration style (i.e. at least one tangiget by column).

Table 2 shows the feasibility of proposing tangigets (from the six categories identified *a priori*) each supporting a collaboration style. Each of them has been developed, integrated in the distributed application described in Section 4, and evaluated. Our objective is to complete Table 2 progressively: we plan to propose, develop and evaluate other tangigets supporting collaboration styles, in future projects.

The method used to propose tangigets supporting collaboration styles is inspired by previous experiments concerning the design of centralized and distributed applications including generic tangible objects (see for instance [28-31]). Brainstorming sessions and meetings were organized to imagine and define new types of tangigets. An iterative approach was used; several versions of these tangigets were proposed and discussed at team level, before their evaluation with groups of users.

3.3. Main generic functions

According to the results of crosses made in Table 2, we identified a set of representative main functions which will be presented later with generic objects that could be used in many collaborative applications on tabletops with tangible interaction. Their main features are presented in Table 3. The set of tangigets was the subject of a case study which is described in the next section.

Table 2. Step 1: Tangigets types crossed with the collaboration styles

<i>Collaboration style</i> <i>Tangiget type</i>	Active discussion	View Engaged	Sharing of the Same View	Sharing of the Same Information but using Different Views	Same Specific Problem	Same General Problem	Different Problems	Disengaged
Tangible control Objects of the application			<i>Proposition of a tangiget called: Starting synchronization</i>					<i>Proposition of a tangiget called: End task</i>
Tangible context objects of the application	<i>Proposition of a tangiget called: Request help</i>							
Tangible control objects of the user interface				<i>Proposition of a tangiget called: Display mode</i>				
Tangible Communication objects				<i>Proposition of a tangiget called: Identification</i>				
Tangible coordination objects					<i>Proposition of a tangiget called: Task assignment coupled with identification</i>	<i>Proposition of a tangiget called: Provide help</i>	<i>Proposition of a tangiget called: Criticism</i>	
Tangible management objects		<i>Proposition of a tangiget called: Task assignment</i>						

Table 3. Step 2: Generic Objects proposed for remote collaboration

Name of the tangiget	Main function	Type of tangiget
Identification	Used to identify users who are currently using the collaborative application and want to enter into collaboration with other users	Tangible communication Object
Task assignment	Used to organize tasks between different users of the collaborative application.	Tangible management Object
Starting synchronization	Used to synchronize the start of the activity distributed on connected tabletops.	Tangible control Object of the application
Request help	Used to ask for help or ask a question about a step or a detail of the collaborative activity	Tangible context object of the application
Provide help	Used to offer help about a step or detail following a request	Tangible coordination Object
Display Mode	Used to change the display of the main interface according to the user needs	Tangible control objects of the user interface
End task	Used to mark the end of a task and / or to switch to another task	Tangible control Object of the application
Criticism	Used to work on all of the activity (not on one task)	Tangible coordination Object

4. Case study

The main aim of this case study is the evaluation of the usability of and satisfaction with tangigets in a case of remote collaboration between users of the system. In previous work, the application was evaluated and validated to be used with children on one single tabletop (so-called centralized context) [2] [31]. So the objective is not to assess the value or usability of the application. The objective is to focus on the tangigets, considered as a remote communication support. For this reason, we performed the case study with adults only in order to better evaluate the tangigets. It is not possible to evaluate this with children between 2 and 6 years of age because they can neither answer the questionnaires, nor follow several strictly planned scenarii.

We chose learning as an illustrative framework for our application; this is because the application is an extension of an earlier application presented in the works [2] and [31]. This case study is based on an exercise concerning the recognition and learning of colors. It is implemented as a distributed application on two interactive tabletops named TangiSense. These tabletops are equipped with RFID (Radio Frequency IDentification) technology and allow the use of tangible objects*. This application extends that previously used in [2] and [31] in a centralized context (i.e. with only one tabletop, with users around it). The new application is called: *Color Learning and Recognition -Distributed Mode*. It is an application intended primarily for children aged between 3 and 5 years old to help them to learn colors using a simple exercise involving the classification of colorless objects. For the purpose of this case study focused on tangigets, a learning situation is simulated using the following principles:

- On one hand, there are two users playing the role of children who are performing the color recognition and learning exercise. They have to place objects "that have lost their colors" (colorless) in suitable color areas (cf. Fig.3a and Fig. 4).. This part of the exercise is inspired by [2] [31] in which the application was validated. For example, the user puts the turtle in the green area. The difficulty level was established by school teachers in the design of the centralized version [2].
- On the other hand, an adult (simulating a parent / teacher) remotely monitors the exercise on his/her own tabletop (located in another room of the house or building, or in another corner of the classroom ...). The content of the tabletop is called "child view"; it is displayed on this tabletop called *adult* tabletop (cf. Fig.3b).

*These tabletops were designed by the RFIdées company (see www.rfidees.com). The basic technologies are described in [32].

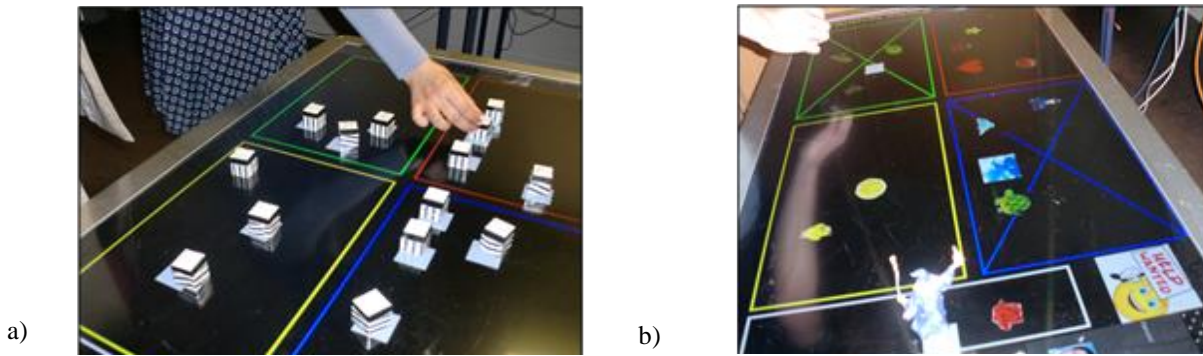


Fig 3. Tangible Tabletops used in the collaborative application: on the left, simulation of the *child* tabletop (two users); on the right, simulation of the *adult* tabletop



Fig 4. Tangible objects to put on interactive tabletop

The application is designed following a set of activities. The expected scenario is shown in Fig. 5. We can observe three main steps: the configuration, the supervised game and the correction.

During the supervised game, if a user with the child's role has a difficulty in recognizing an object, he/she puts this object in the white area. Then the supervisor (user on *adult* tabletop) can help him/her by crossing one or several colored areas. In Fig. 6, we can see the *adult* tabletop with the green area marked with a cross. We hope that the distant children understand, because of the cross, that this area is not the solution for the object which requires help.

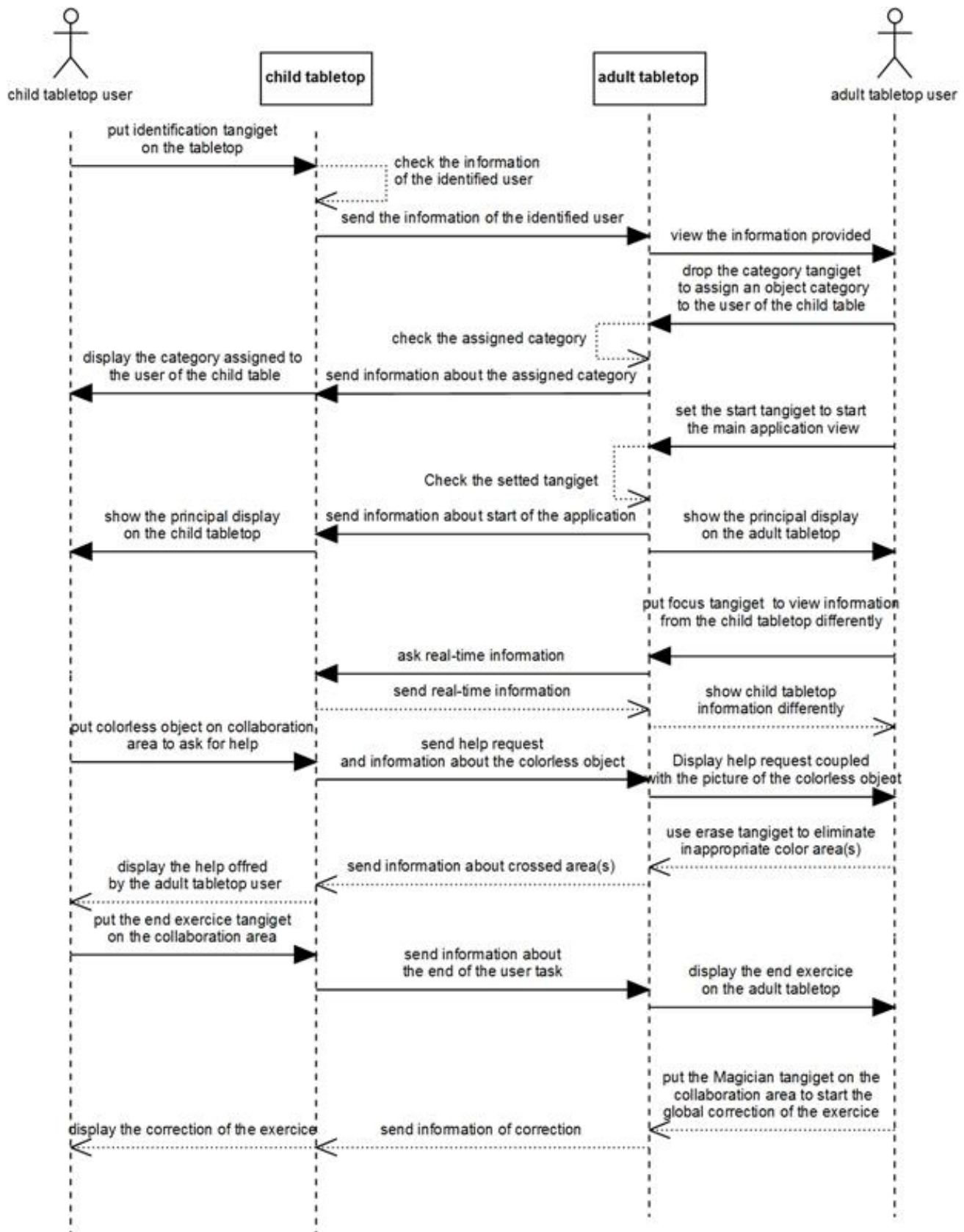


Fig 5. Sequence diagram of the distributed application *color learning and recognition*

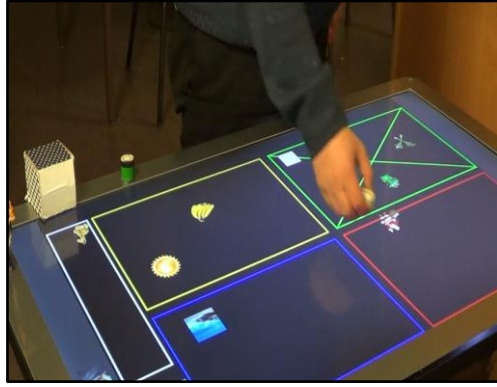


Fig 6. Participant on *adult* tabletop crossing color area to help remote collaborators to find the right color for a colorless object which is in the collaboration area, on the left on the picture.

4.1. Available tangible objects

This system proposes some tangible objects (tangigets or specific objects to the application) with a set of features for users (This list details and applies the initial proposition given in [33]):

- **Identification:** children can remotely identify themselves in order to declare their presence to the adult and to ask for permission to play. The required tangiget can be associated to the task "Child Identification".
- **Task Assignment:** there are 4 groups of objects; each category contains 8 colorless objects to be placed in the appropriate color area. Each category contains items of different difficulty levels (3 easy, 3 medium difficulty and 2 difficult). When the child is identified, the adult assigns a category of object to him/her. The child will play with this category throughout the exercise. The required tangiget can be associated to the task "Object Category Assignment".
- **Starting Synchronization:** the adult can start the application on both tabletops to control the beginning of the exercise. The required tangiget can be associated to the task "Starting application".
- **Display Modes:** the main user interface displayed on the *adult* tabletop is the same as the one displayed on the *child* tabletop by adding the image of objects placed by the child (or children). The adult has the opportunity to change the main display mode on the tabletop while keeping the same content. The required tangiget can be associated to the task "Changing Display Mode".
- **Help Request:** If the child encounters a difficulty with the color of an object, he or she can request assistance from the adult who uses the remote connected tabletop. The required tangiget can be associated to the task "Request help about a colorless object".
- **Provide Help:** following a request for assistance, the adult can help by limiting the number of choices on the *child* tabletop. The required tangiget can be associated to the task "Provide help about a colorless object".
- **End Task:** once his or her eight objects are placed in areas of color, the child may declare that his/her exercise is finished and that he/she is waiting for the correction. The required tangiget can be associated to the task "End exercise statement."
- **Criticism:** if children have completed their exercise, the adult can initiate a remote correction for them to discover any mistakes and try to correct them. The required tangiget can be associated to the task "Exercise correction".

To carry out this study, we used two interactive tabletops with tangible interaction, a set of colorless objects and, to meet the remote collaboration needs, a set of tangigets that covers all the categories of tangiget which were proposed. Table **Erreur ! Source du renvoi introuvable.**3 shows the instantiation of the generic objects (with a picture of each item): they correspond to concrete software implementations of the tangigets identified above (see Table 2), covering the different collaboration styles.

Table 4. Instances of tangigets used for the application

Name of tangiget	Used object in the application	Definition of its role
Identification	Identification 	Used to identify the person present remotely and ready to play
Task Assignment	Category 	Assign a category of object to the person identified
Starting Synchronization	Start 	Start the game on the two connected tabletops
Help Request	Collaboration area 	Request remote assistance by placing object(s) requiring help in this area
Provide Help	Erase 	Offer help by crossing color areas
Display Mode	Focus 	Display the results of the exercise (textual representation)
End Task	End exercise 	Indicate the end of the exercise for each user
Criticism	Magician 	Correct remotely the exercise

4.2. Participants

We recruited 12 groups of 3 participants who were not familiar with the use of tabletops. They all came from the lab and were not paid for this study. These 36 participants are adults and have a globally homogeneous level of education (master's degree level or higher). Each group consists of three people, two in the role of children and the third to represent the adult. We choose participants with the child roles in order to evaluate the collaboration with tangigets, the "color learning" part having already been tested in [31] and because it is easier for adults to answer questionnaires. The 12 groups are named G1 to G12.

Members of each group knew each other and had worked together; subjects were colleagues, friends, members of the same family, or married couples. Participants were aged 23-49 years old (the average age was 27 years old); 3 groups were mixed; 4 groups included only women; 5 groups included only men.

4.3. Procedure

Participants were initially settled around a tabletop to fill out a form with information about their age, their gender, and their potential eyesight problems (corrected or not). Some questions were designed to estimate their knowledge of large interactive surfaces, to know their work habits in a group, and use of sharing and collaborative systems (Skype, teamviewer, etc.).

A presentation of the system and its functioning as well as the functioning of each tangiget was given (this familiarization phase was about 10 minutes long per group). The presentation was performed using a @Microsoft Powerpoint presentation (18 slides) so that the content was presented to each group in an identical fashion. It was followed by a familiarization phase with the interactive tabletops during which participants were encouraged to try the application and all items offered and ask questions freely. A picture of the room during this situation is shown in Fig. 8. We can see the *child* tabletop with 2 participants and the *adult* tabletop with only one participant. We can see that this picture corresponds to the familiarization phase because the participant with the *adult* role does not yet have his audio headset on.

After this phase of familiarization with the system, the tabletops and the tangible objects, tests were started with different scenarios provided. We designed three conditions that varied aspects of the use of the aid application and the correction of the exercise with the help of the remote participant at the adult tabletop. In these different conditions, instructions were provided to users of the *child* tabletop:

- One of the scenarios is so-called *free*, no remarks or requests were made either to the users with *child* roles or to the user with the *adult* role. The goal of this condition is to see the behavior of all participants and to see which tangigets they use.
- The second scenario, named *with assistance request* shown in Fig. 7., consists in giving the instruction to adults with a *child* role to put objects as they wish in the collaboration area to request help. The goal is to see if the participant with the *adult* role sees the request, how he/she reacts, and with which objects.
- Then, the third scenario, named *with misplaced objects*, gives the instruction to participants with a child role to make a mistake in the placement of object. The goal is to see if the participant with the adult role proposes help (with the erase object which crosses an area), gives a result (with the magician) or does nothing about the help request.

We can see in Fig. 7 that the conditions were counterbalanced. For each group, we give a definite number of mistakes and requests for help: *4 wrongly placed objects* (refers to the scenario: *with misplaced objects*), *4 requests of help* (refers to the scenario: *with assistance request*) and *free use* (refers to the scenario: *Free*). In Fig. 7, we explain in detail all the slots available in this evaluation. The members of the test groups worked for an average of 7 minutes in each condition.

Fig 8. provides an illustration of the three participants in a test group set in relation to their different roles (2 participants at the *child* tabletop, and one at the *adult* one). To simulate remote collaboration, participants were in the same room but the two tabletops were separated by a folding screen to prevent users of each tabletop from seeing the contents of the other tabletop. Moreover, to prevent the participant at the *adult* tabletop from being disturbed by possible natural discussions coming from the *child* tabletop, he/she had a headset on with music playing.

Two cameras, one per interactive tabletop, allowed us to capture the progress of the test on the tabletops.

After the study, each participant had to complete a questionnaire, called questionnaire #2 (available in the annex). The questionnaire firstly concerned information on usability aspects and participant satisfaction with the system. Secondly,

he/she had to fill in more specific information on generic objects, ease of use and their significance in relation to their role set by the designer.

Finally, the investigator used a log file in which all the games played by the group were recorded in order to understand how they had addressed the problem and to get their responses on the technologies and principles used.

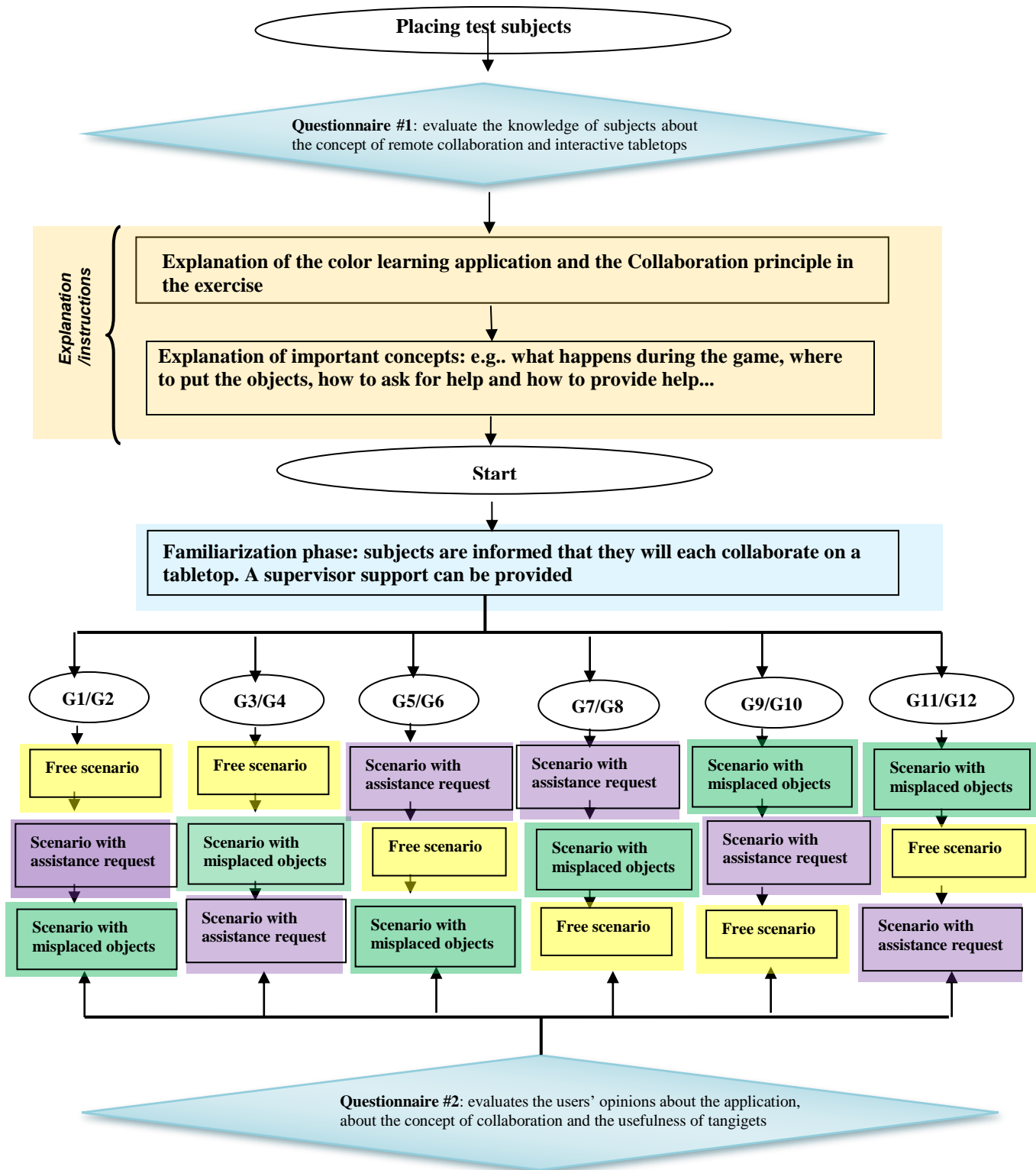


Fig 7. The schedule of test steps for each test group



Fig 8. Picture of three participants during the familiarization step.

5. Data analysis

The data analysis will be detailed in three parts. The first one concerns observations made during the study in order to detect particular behaviors or problems encountered by participants during the interactions. It is followed by an analysis of subjective data collected through the questionnaires completed. Finally, an analysis of objective data regarding the analysis of log files from the records for all the sessions is presented.

5.1. Results concerning the observations

In all conditions, the group members contributed to a significant collaborative exchange, using the functionality provided by the system through tangible objects and explored different uses of the tangigets to produce appropriate results. They engaged in both individual and group work, in turn and / or simultaneously.

Concerning *child* tabletop, the participants on the children's side used the tangigets to communicate and to ask questions about objects that are difficult to recognize (e.g. lettuce, police car, ...), identifying themselves by placing the identification object on the tabletop, placing an object (sometimes two or more at a time) in the collaboration area or signaling the end of the exercise.

They collaborated both remotely and in a co-located manner. They were organized to identify themselves as well as to place colorless objects or to request assistance.

From video recordings, we noted some questions about unidentified objects (request for help between participants on the *child* tabletop).

Frequent questions were for example:

- "Which avatar do you prefer to play with?" (Avatar = tangiget identification)
- "Are bananas yellow or green?"
- "Are policemen's clothes always blue?"
- "Put your object in question, I'll ask mine after you"

In a single test, participants on the *child* tabletop swapped their colorless objects by mistake, and quickly noticed their error.

On the *adult* tabletop, the participants used the tangiget items to meet the remote requests: Task assignment (*category*), Provide help (*Erase*) and Criticism (*Magician*) to guide the "children" by showing them the exercise correction when they wished. There was a reluctance to use some tangigets, but after the first use, a frequent use of all the proposed tangigets was

noted. There were actions performed by children to which some adult participants responded in two different ways. An example of this was the exercise correction; instead of placing the magician tangiget to solve the exercise, two adult participants used the erase tangiget to cross color areas that contained misplaced objects (same goal, two different ways).

5.2. Results concerning the analysis of subjective data

The questionnaire #2 was used to seek the opinions of participants on the *usability* of tangiget objects, *meaning of objects*, and *ease of understanding* of the remote communication with the other tabletop. We use a Likert scale with 5 points.

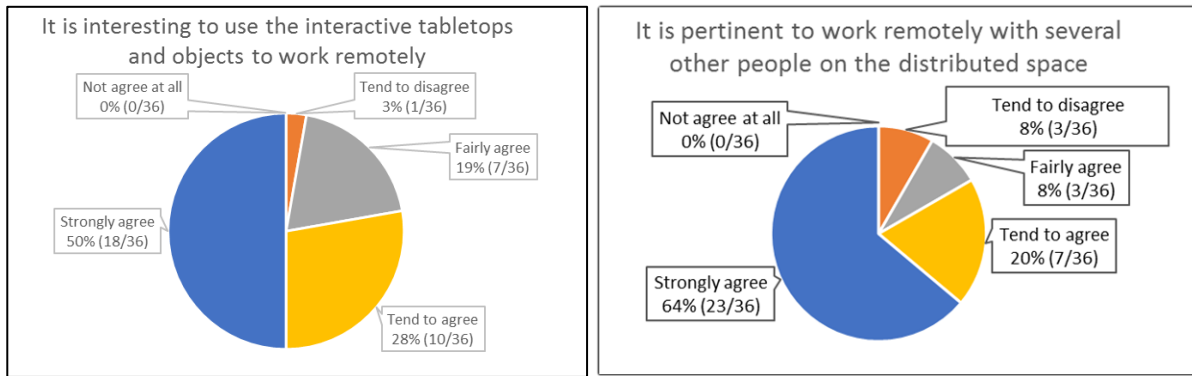


Fig 9. Graphics representing the user answers about the use of the system in general

We can see in Fig. 9Fig the points of view of all users who tested the system concerning their use of the *distributed application on interactive tabletops with tangible objects*.

Most answers fall into the *Tend to agree* to *Strongly agree* categories, which shows that the application has convinced most of the participants to use such applications and platforms to perform collaborative tasks or activities.

In addition, to collect the participants' feedback on the tangigets used during the study, we asked for their opinions about two points for each tested object:

- The object has a significant role. This provides a first tendency about the utility of each object.
- The object is easy to handle. This provides a first tendency about the usability of each object.

Questionnaires concerning the tested items were distributed to the users according to their roles in the application. That is why the 12 participants on the *adult* tabletop answered questions about five generic objects: Task Assignment (name of the implemented tangiget: *Category*, see Table 4), Starting Synchronization (*Start*), Criticism (*Magician*), Provide Help (*Erase*), Help Request (*Collaboration area*) and Display Mode (*Focus*). The 24 participants on the *child* tabletop responded to questions about the three generic objects concerned: Identification (*Identification*), Help Request (*Collaboration area*) and End Task (*End Exercise*).

According to user responses for the first question, "The object has a significant role", we can classify tangigets into two categories:

- Tangigets that have a high match between their allocated roles and forms: *Identification*, *Category*, *Start*, *End exercise* and *Collaboration area*.
- Tangigets that have a medium match between their allocated roles and forms: *Focus*, *Erase* and *Magician*

According to user responses for the second question, "The object is easy to handle", we can classify tangigets into two categories:

- Tangigets whose shape is highly good for its use and handling: *Identification*, *Start*, *End exercise* and *Collaboration area*
- Tangigets whose shape is moderately good for its use and handling: *Magician*, *Focus*, *Erase* and *Category*.

We note that none of these tangigets was low classified for both questions which proves that all the proposed objects were accepted in general. All the results are shown in Fig. 10.

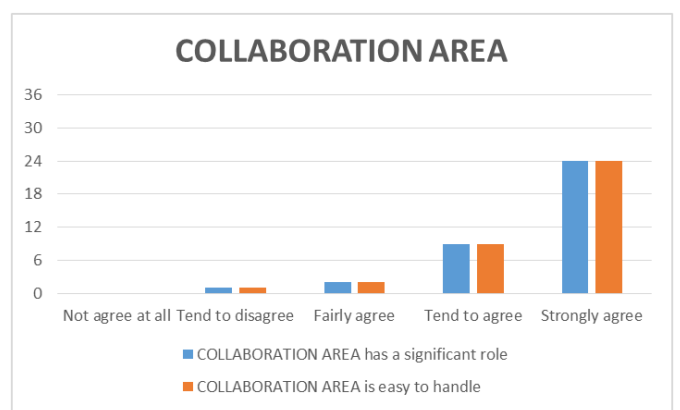
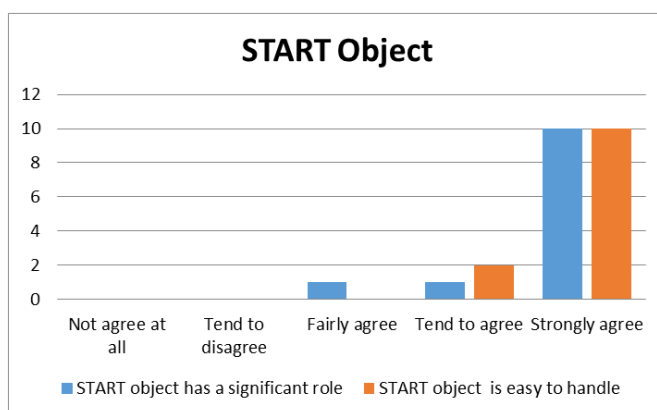
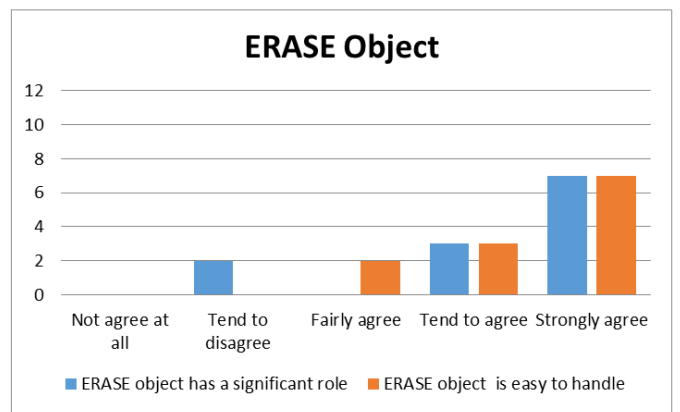
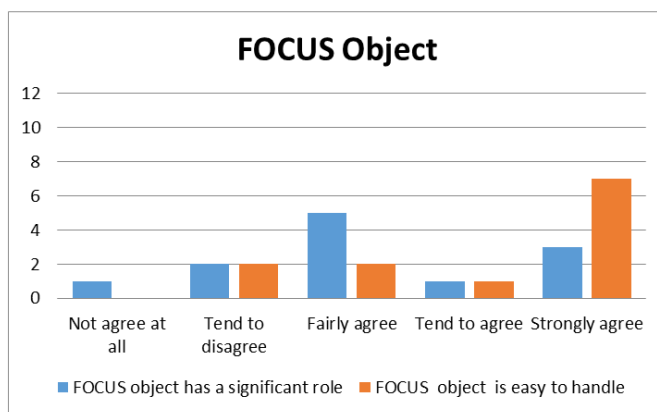
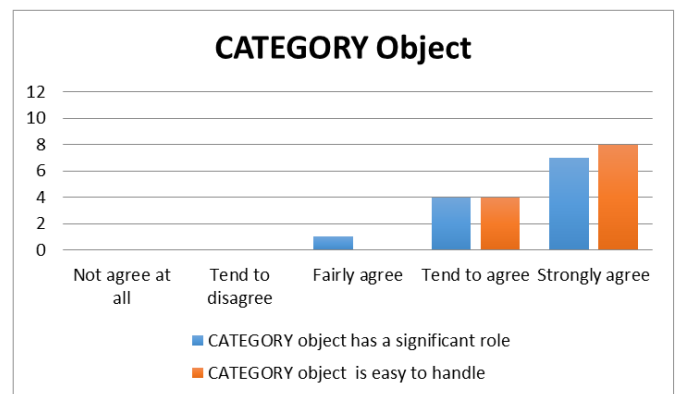
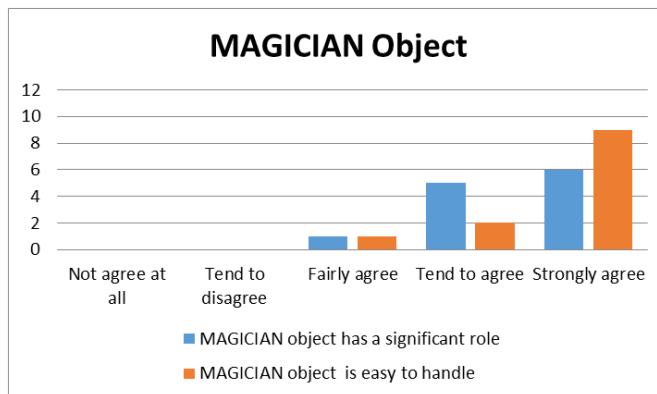
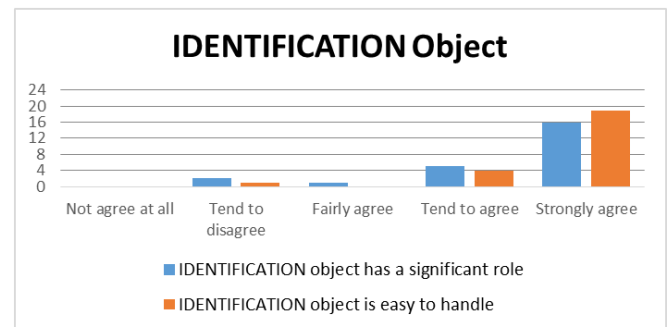
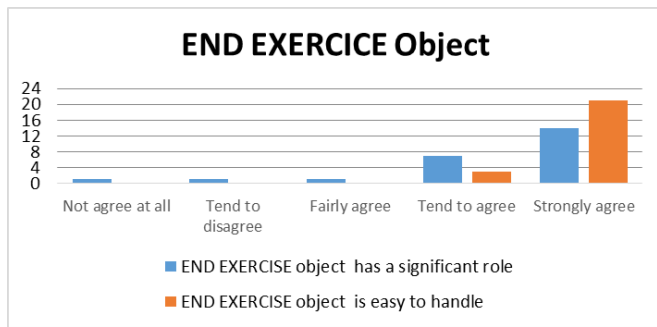


Fig.10 Graphs representing responses of participants who used the tangigets

5.3. Results concerning the analysis of objective data

To verify the results collected through questionnaires, we used log files which result from the recording of all the operations performed during the study. These results are presented in Fig. 11 and Fig. 12 as a set of responses (actions) made following an action by the remote users. By response, we want to categorize the behavior of the collaborator following an activity or an action performed on the remote tabletop by its user (example: following a request for help made by a user on the *child* tabletop, the expected response by the user on the *adult* tabletop is the use of the *Provide help* object). According to the response received, we classified them into three categories:

- **Expected response:** if the user used the adequate object made to meet the action.
- **Acceptable response:** if the user used the adequate object but in a manner other than that set by default, or if he/she used another object that could match with the action in a way.
- **Incoherent response:** if the user used a totally incoherent object for the due action.

From our analysis of log files, we found no significant differences between the behavior of users and their responses with the system and generic objects. Thus, we report the cases applicable to all groups, regardless of the condition.

Fig 11 and Fig 12 show the number of expected, acceptable and incoherent responses for each task in the scenario. The maximum number of responses depends on the tasks. In Fig. 11, tasks are done only once so the response total is 72. In Fig 12, the total depends on the task (from 153 to 26). In Fig. 11 and 12, we see an absence of incoherent responses; for acceptable responses we notice that the rate varies, the responses where the rate of acceptable responses is larger are "*adult affects a category to the child*", an action that uses the "*Category*" object and the action "*the adult poses the magician for correction*" that uses the "*Magician*" object. We find that these results clearly support the user responses to these objects because the wrong understanding of an object generates its incorrect use.

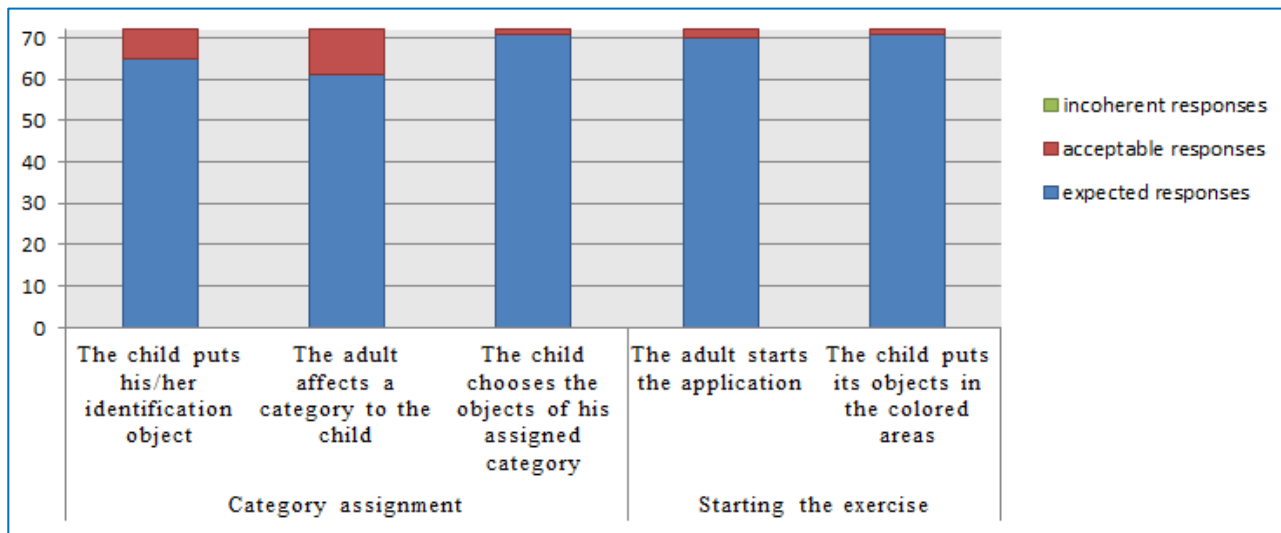


Fig 11. Classification of participants' responses on received actions using tangigets for category assignment and starting the exercise tasks

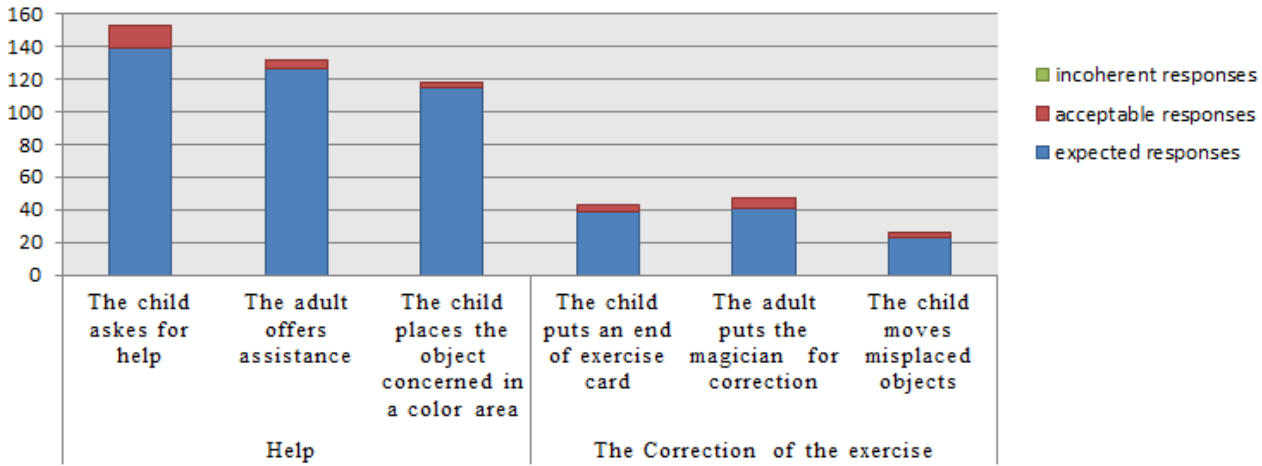


Fig 12. Classification of participants' responses on received actions using tangigets for category assignment and starting the exercise tasks

Users in the different conditions (*Free*, *With assistance request* and *With misplaced objects*) seemed have almost no difficulty interacting with the system and each other. The speed of handling tangigets and business objects increases according to the number of tests done. In fact, the average time spent by participants during the first iteration for the 12 groups was calculated, giving a result of 6 minutes. The average for the same measurement at the end of the 4th iteration was about 3 minutes. One can consider that there is a learning effect.

6. Discussion

From an overall point of view, test results show varying responses but which are more concentrated in the Tends to agree and Strongly agree categories. This demonstrates a remarkable acceptance of the application and tangigets used, without knowing if there was a novelty effect (other experiments would be necessary to show or mitigate this effect).

This study showed that users of the application were able to use tangible objects to communicate and collaborate remotely. We also found that most of the participants' responses, such as the answer for a remote action performed on the other table, were the expected ones. Some were acceptable and none were incoherent.

From a detailed point of view, we found a strong link between the results collected during the study and those collected through the post-test questionnaires (questionnaire #2 in Fig. 7). In fact, if we take the results of the questionnaires completed by the participants as a starting point, we note that the average response varies from one object to another. For example, there is a response rate of *Strongly agree* for the tangigets *Erase*, *Start*, *End exercise* and *Collaboration area* which is greater than for the generic objects *Category*, *Focus*, *Magician* and *Identification*. If we make the link with the results of log files, we found a lower average of *expected responses* compared to *acceptable responses*.

If we look for an explanation for the rare cases in which participants used the non-reserved object for the task, we can explain this result by the fuzzy choice of the physical shape of the tangiget in relation to its main role in the application or the crossing of tangiget features

For example, if we compare the features of both tangigets *Erase* and *Magician*: *Erase* is used to help the child to find the right color of the colorless object placed in the collaboration area, by excluding two of the non-appropriate color areas. The reserved collaborative style for the *Erase* tangiget is the treatment of the SGP (*Same General Problem*). In fact, when *Erase* is placed on the *adult* tabletop in a color area, this area will be crossed out and the child must choose between the other three choices for placing the object. *Magician* has a different function but relatively similar to erase. It is reserved for the treatment of DP (*Different Problem*). In fact, by placing the *Magician* on the *Collaboration area*; it corrects the learning exercise on the *child* tabletop and crosses out any misplaced objects. If a colorless object is out of the four colored areas, it is not concerned by the correction of the exercise. In addition, in the current version, the user must place the *Erase* object in the collaboration area to remove the information bar from color areas. This statement is not obvious to a user who is managing an interesting set of features and generic objects at the same time. Because of this, we find answers to the questions "*Erase* object: has a significant role" and "*Erase* object is easy to handle" that are in the *Tend to Agree* and *Fairly Agree* categories.

Two conclusions can be drawn from this analysis: (1) In some cases, users use the tangiget *Erase* for the criticism phase and prefer to cross the area which contains the misplaced objects rather than placing the *Magician* and correcting the

exercise at the same time. The use of the two tangigets (*Erase* and *Magician*) intersects in the fact that both show the state of the answer (false / correct), so we can understand the misuse. To avoid this, in our future works we should focus on the concepts of affordance of tangible objects and apply different features [26] [34]. (2) Users prefer to even remotely interact about the same problems in real time rather than treat each problem separately; in fact, the use of SSP (*Same Specific Problem*) and SGP (*Same General Problem*) collaboration styles is more frequent than the use of DP (*Different Problem*). We can say that real-time interaction about a common task is more obvious to users in remote collaboration. The treatment of different problems seems to need more precision in the use of tangiget representation.

We proved through this study that we can collaborate remotely and work on tasks in common with other distant people while using only interactive tabletops and a set of tangible objects. The specificity of our approach is that we only used the tabletops and their capacity to get information without having to use other communication tools as in most of the work using the concept of hand shadow simulation of other remote collaborators via video capture [20] [24], or by using video conference tools such as in the work of [35].

The above results about the use of interactive tabletops and tangigets show that the use of interactive tabletops can have a positive effect on remote collaboration. First, depending on the situation of this collaboration, we can say that users succeed in their assigned tasks. They respect the sequence of the application while learning how to manipulate the tangigets (response time and number of errors decrease). The results could also indicate an ease of use of the platform, despite their non-familiarity with interactive tabletops beforehand.

Secondly, the use of all tangigets proposed for this application, which cover all styles of collaboration identified above, shows that the concretization/realization of our approach (based on the idea of succeeding in all styles of collaboration through interactive tabletops) is possible. Moreover, all users understood the purpose behind these tangigets and used them one by one in the correct way (a majority of expected answers, few acceptable answers, and no incoherent answers).

7. Conclusion

In this paper, we presented an exploratory study of a proposition based on distributed user interfaces on remote tabletops equipped with RFID technology allowing the automatic detection of tangible objects. These tabletops are also equipped with a large OLED screen to provide a display. We investigated remote tabletop collaboration using remote arrangements based on tangible generic objects, called tangigets. These tangigets allow a set of functionalities that facilitate the communication and the arrangement of tasks between distant users. The tangigets are coupled with the display to provide a multimodal user interface.

Collaboration using remote tabletops totally or partially covers a set of collaboration styles. We suggest the effects of covering all those styles with tangigets that we can use in different collaborative applications on tabletops using tangible interaction.

To validate our contribution, we propose a distributed application which allows collaboration between remote users; this collaboration was concretized thanks to a set of tangigets designed and made for the application.

The results of the tests of the application are presented and analyzed in two parts (1) subjective results, which are based on questionnaire answers and (2) objective results, which are based on log file analyses and observations; we found that the operational principle of tangigets is accepted by users. They also materialize well the principle of collaboration targeted by the application by offering many different styles of collaboration, both simple and fast.

In our future works, we aim to test the principle of generic objects with another collaborative application which integrates more collaborative activities and more difficult tasks; we also aim at a wider use of tangigets with more than two tabletops and between tabletops and other platforms. Another evaluation track can also be highlighted regarding the evaluation of the behavior of children when they are playing and interacting with interactive surfaces such as in the works of [36]. Finally, this study gave us other ideas about how we can exploit the platform more, such as the integration of multiple tangigets in one application that support the same style of collaboration in order to test user preference about an object's form and presentation (affordance of objects). We also aim to include the ability of taking decisions about the possibility of remote collaboration; such a scenario would help us to study user preferences about remote collaboration (full collaboration, partial or avoid).

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Annex: Questionnaire 2

EXAMPLE OF USE: Do you buy candies? - Answer: "rarely" and "I'm almost certain"

No at all	1	2	3	4	5	Totally

No at all certain	1	2	3	4	5	Totally certain

Evaluation of the usefulness of tangigets used to collaborate remotely via tangible interactive tabletops

I. Evaluation of the usefulness of tangigets used to collaborate remotely via tangible interactive tabletops (To be completed by users on *adult* tabletop)

1. Does it seem relevant to work remotely with others on the distributed space offered by the connected interactive tabletops to achieve color learning or for other applications?
2. Does the "Category" object seem significant to you in relation to its roles in the application?
3. Can you handle the object "category" easily?
4. Does the "Start" object seem significant to you in relation to its roles in the application?
5. Can you handle the object "Start" easily?
6. Does the "Magician" object seem significant to you in relation to its roles in the application?
7. Can you handle the object "Magician" easily?
8. Does the "Eraser" object seem significant to you in relation to its roles in the application?
9. Can you handle the object "Rubber" easily?
10. Does the "Focus" object seem significant to you in relation to its roles in the application?
11. Can you handle the object "Focus" easily?
12. Does the "Collaboration Area" object seem significant to you in relation to its roles in the application?
13. Can you handle the object "Collaboration Area" easily?
14. Are you able to understand the identification of remote table users?
15. Was the request for help clear?
16. Were the objects subjects of a request for help clear?
17. Was the declaration of the end of the exercise clear?

II. Evaluation of the usefulness of tangigets used to collaborate remotely via tangible interactive tabletops (To be completed by users on *child* tabletop)

1. Does it seem relevant to work remotely with others on the distributed space offered by the connected interactive tabletops to achieve color learning or for other applications?
2. Does the "Identification" object seem significant to you in relation to its roles in the application?
3. Can you handle the object "Identification" easily?
4. Does the "End exercise" object seem significant to you in relation to its roles in the application?
5. Can you handle the object "End exercise" easily?
6. Does the "Collaboration Area" object seem significant to you in relation to its roles in the application?
7. Can you handle the object "Collaboration Area" easily?
8. Was the request for help easy?
9. Was the help provided by the remote user of the other table clear enough to help you find the right zone for the object in question?
10. Was the correction of the exercise clear enough to correct the errors?
11. Was the assignment step of the category clear?