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Influencing Participation in Group Brainstorming through Ambient Intelligence

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Influencing Participation in Group Brainstorming through Ambient Intelligence

Drawing on concepts from theories on persuasion, social psychology and philosophy of language, we designed an ambient persuasive system that acts as an automatic facilitator by supporting a balanced flow of communication in group conversational activity. The system includes two main components: a) a context-awareness system that monitors group member non-verbal behavior and b) a visualization component that promotes balanced participation, providing targeted directives to participants through peripheral displays. In two empirical studies, we assessed a strategy for influencing participant social dynamics based on subtle directives in the form of aesthetically pleasant visual animations. The findings provide insight on the effect, the acceptability and the perceived influence of subtle peripheral persuasive messages for ambient displays. Our studies indicate that when the participants understand the message intention, the subtle directives have a positive influence on group behavior, and are considered more appealing and less intrusive than overt, language-based messages. Furthermore, we found that personality traits influenced attitudes towards the system.

Keywords: ambient persuasive system, group persuasion, persuasive strategies, ambient influence, group brainstorming

Introduction

This paper presents an ambient persuasive system designed to influence a co-located small group of people engaged in a joint conversational task. The main focus is to investigate how a system that continuously tracks user behavior can be used to plan and execute persuasive strategies aimed at influencing social interaction through Ambient Intelligence. Ambient Intelligence — the pervasion of everyday life with information technology that is responsive to the presence of people — has an enormous potential for investigating persuasive technologies integrated into the environment. In this context, one interesting challenge is to study communication strategies that involve unobtrusive and subtle interaction compared to direct and focal persuasion employed in traditional approaches. In this regard, several concepts and ideas have been proposed and developed in HCI such as Ambient Persuasive Systems (Kaptein, Markopoulos, Ruyter, & Aarts, 2010), Implicit Interaction (Schmidt, 2000) and Ambient Influence (Rogers, Hazlewood, Marshall, Dalton, & Hertrich, 2010).

Two fundamental aspects characterize persuasion in Ambient Intelligence:

(i) ambient persuasion should preferably be implicit rather than explicit (Schmidt, 2000) in order to avoid distressing the user with excessive attentional demands and

(ii) persuasive strategies should preferably target groups rather than a single individual in order to take advantage of the public nature of spaces in which the technology is embedded.

These characteristics of ambient persuasion required a deep understanding of how persuasive systems can unobtrusively influence users without requiring their focal attention, and how technology can mediate and influence social interaction in co-located groups of people that are characterized by specific social processes and group dynamics.

To investigate these characteristics of Ambient Intelligence, we designed and evaluated an ambient system that acts as an automatic mediator by facilitating group participation in a brainstorming activity. This ambient persuasive system (i) is based on continuous awareness of people's behavior, (ii) is able to understand (to some extent) the social dynamics occurring within the group and (iii) can intervene to influence the behavior of group members. Specifically, the system aims at balancing the contributions of group members in order to foster a more balanced participation. The prototype has the shape of a small table and is placed in the middle of the group. The table incorporates sensing devices (cameras and microphones, even though only information from the camera sensor was used) to track group behavior and it visualizes persuasive messages through embedded displays. The prototype was evaluated in two user studies and the results suggest that subtle unobtrusive visualizations might be an effective way to “nudge” participants’ behavior and influence group dynamics.

In the next sections, we review related research, outline the conceptual foundation for the design of our ambient persuasive systems, describe the technology for sensing the social context and use of persuasive messages, and present the empirical studies for evaluating the effect of the system on the conversation of participants. Finally, we discuss lines for further research on persuasion in Ambient Intelligence.

Relevant Theories

Behavioral change theories are psychological theories and theoretical frameworks for the prediction and change of human behavior. These theories have their roots in social psychology and behavioral economics, and are meant to explain the factors determining behavior and guide the development and the assessment of behavioral-change actions. The design of our system, and of the persuasive strategies currently used, was inspired and guided by these theories, in particular by the Theory of Planned Behavior (Ajzen, 1991) and by the Nudge Theory (Thaler & Sunstein, 2008).

The Theory of Planned Behavior

In social psychology, attitudes are individual global evaluations of people, objects, events or ideas that influence thought and action (Perloff, 2003). An attitude involves a predisposition toward certain ideas, values or institutions while behavior relates to the actual expression of actions and feelings through verbal or nonverbal communication (e.g. gestures or body language). According to the Theory of Planned Behavior (Ajzen, 1991), the relationship between attitude and behavior is not straightforward. Attitudes do not always lead to concordant behaviors and many variables might influence the prediction of an intended behavior, such as behavioral intention and subjective norms.

The Theory of Planned Behavior was developed from the Theory of Reasoned Action, originally proposed by Ajzen & Fishbein (Ajzen & Fishbein, 1977). The Theory of Reasoned Action assumes that people consider and reason on the consequences of their behavior before performing it. Behavioral intentions develop from the personal individual's attitude toward the behavior and the individual's impression of the way other people perceive such behavior. Therefore, personal attitude and social evaluation influence behavior intention, which is essential to the performance of a behavior and, consequently, to behavioral change. The Theory of Reasoned Action was later expanded in the Theory of Planned Behavior (Ajzen, 1991) to include the role of perceived behavioral control — the extent to which people believe they can perform the behavior. According to the Theory of Planned Behavior, behavior intention is determined by three dimensions: the level of control of an individual over the behavior, the strength of the individual's attitude in performing the behavior, and their subjective norms. The Theory of Planned Behavior has been further refined into the Reasoned Action Approach (Fishbein & Ajzen, 2011), a framework for behavioral-change interventions that proposes strategies for motivating people to engage in a behavior and to implement their intentions. The Reasoned Action Approach describes strategies for evaluating the success (or failure) of behavioral-change interventions.

This approach to persuasion aims at changing behavior by influencing the attitude of an individual toward the targeted behavior. Several persuasive systems (Oinas-Kukkonen & Harjumaa, 2009), including ambient persuasive systems (Kaptein et al., 2010), adopted this approach by influencing individuals to change their attitudes.

In our approach, we took the stance of the Theory of Planned Behavior on how attitudes are related to behavior, but we adopted a different perspective: we aim at changing micro-behaviors in order to possibly induce a change in the attitudes, rather than the other way around. As a matter of fact, our goal is to suggest small behavioral changes that will have short-term consequences. In order to achieve this, we followed the approach of the Nudge Theory (Thaler & Sunstein, 2008).

Nudge Theory and Behavioral Nudging

The Nudge Theory (Thaler & Sunstein, 2008) is a multidisciplinary approach to persuasion that proposes the use of positive and indirect suggestions, in the form of "nudges", for guiding decisions. The Nudge theory is based on concepts from behavioral economics and the psychology of decision-making, and has been applied in ICT research in domains including health and sustainability (Hekler, Klasnja, Froehlich, & Buman, 2013; Lee, Kiesler, & Forlizzi, 2011).

Nudge theory suggests that positive reinforcement of behaviors, conveyed through subtle suggestions and hints, can influence motivation, collaboration, and decision processes, even in a subconscious manner. At the core of the theory is the concept of "nudging": indirect and subtle suggestions that should have the power to influence and guide individuals and groups towards the desired behavior. Examples of nudges would be putting fruit at eye level in a cafeteria for promoting a healthy food choice (Thaler & Sunstein, 2008), or using lights to encourage people to take the stairs instead of the elevator (Rogers et al., 2010).

In substance, nudging is a behavioral change strategy that influences less conscious decision processes compared to other persuasive strategies, such as feedback or recommendation. In some conditions, nudges are considered to be as effective as, or even more effective than overt suggestions. A successful nudge requires that individuals be unaware that an external actor or source is influencing their decisions and subsequent behaviors. To this end, persuasive messages should be designed as subtle messages, so they can influence people's behavior towards the desired direction without requiring the individual's complete attention. In this perspective, a successful nudge is any action in the immediate environment that indirectly influences a desired behavior, and makes that behavior more likely to occur.

The Nudge Theory has been mainly discussed within decision-making and behavioral economics research; in our study, instead, we designed a persuasive strategy based on this theory, and adopted a minimal and simple form of behavioral nudging for promoting micro-changes in group member behavior. Our concept of ambient influence is indeed close to nudging, since we investigate the use of peripheral, aesthetically pleasant visualizations as a form of subtle messages that could nudge the group to change its behavior.

Persuasion and Influence in Co-located Small Groups

Research on social and group psychology has explored different social processes that occur while people are interacting in small groups, including group dynamics involved in influence and persuasion. Much of the empirical investigations on these topics have been carried out by evaluating group performance and dynamics in a variety of scenarios including decision-making, problem-solving and creativity tasks (Kerr & Tindale, 2004). Considerable research has explored group dynamics during idea-generation tasks, such as group brainstorming. Group brainstorming is a method for promoting creative thinking in groups popularized by Osborn (1953) that is also used for investigating the processes of group creativity and teamwork (Paulus, Putman, Dugosh, Dzindolet, & Coskun, 2002).

A main finding in this research area is that groups do not always facilitate group creativity, but can often hinder the effective exchange of ideas (Diehl & Stroebe, 1987). A group of people who do not know each other very well might in fact encounter a number of cooperation barriers when they are asked to collaborate in a group activity. Specific to brainstorming tasks, empirical studies have identified five different barriers that might emerge and influence group activity (Diehl & Stroebe, 1987; Paulus et al., 2002): production blocking, free-riding, evaluation apprehension, cognitive inertia and group (un)awareness. While waiting for their turn, people may forget some ideas before they can report them, and they may not generate new ideas or may be distracted while listening to others (*Production blocking)*. Participants may reduce their effort because they think that the effort of the other members makes up for their reduced output (*Free riding*). Productivity also decreases when members become personally concerned with how other members may react and respond to their ideas (*Evaluation apprehension)*. A further obstacle is that people might stick to a limited set of ideas, which was voiced at the beginning of the brainstorming session (*Cognitive inertia*). Lastly, on the one hand a continuous *awareness of the group process* may disturb the creative flow and therefore cause production blocking; on the other hand, being aware of what others are doing may serve as an additional prompt, which inspires creative work and group cohesion.

Building on the knowledge of these barriers to creativity, many studies have investigated methods for improving traditional group brainstorming, such as adding defined rules or guidelines to the task, using technological support (the so-called *electronic brainstorming*), providing structured group training or involving trained facilitators. Several studies have found that the use of a facilitator can minimize both production blocking and evaluation apprehension, improving the participatory climate and increasing group discussion (Baruah & Paulus, 2009; Burns, 1995). The group facilitator, who is not a member of the group, has the main task of helping the group to interact in a more efficient way. A common function of such a facilitator is to ensure that all team members contribute, giving everyone a chance to participate in the discussion. In fact, unbalanced participation might lead to low involvement in the discussion by some members, which, in turn, might result in a loss of motivation for the other participating members and, eventually, in lower learning and performance outcomes. On the other hand, balanced participation is a target situation in which members of a group participate equally in the activity. Balanced group participation tends to favor information sharing and foster the creative process of building on one another's ideas. Equal participation alone cannot guarantee a positive outcome of a conversation in terms of group engagement and productivity; nevertheless, it is a beneficial condition for successful group dynamics in creativity tasks.

Related Work on Ambient Technology for Co-located Groups

Having discussed the relevant theories, in this section we introduce the background technological context for our work, as it is related to the Nudge Theory and Ambient Intelligence: ambient displays. An ambient display is defined as an information system that displays non-critical information by providing aesthetically pleasing visualizations in a non-obtrusive manner (Pousman & Stasko, 2006). Originally, ambient displays were designed for peripherally representing in a pleasant manner processes that are hard-to-see or ephemeral, such as stock market data, weather forecasts (Pousman & Stasko, 2006), aspects of personal lifestyle such as sustainability (Nakajima & Lehdonvirta, 2011) or social dynamics, such as the amount of group discussion during a task (Bergstrom & Karahalios, 2009; DiMicco, Hollenbach, Pandolfo, & Bender, 2007). The main idea is that people should need quick forms of interaction with ambient technology, such as glancing at the display when walking past, to understand and infer the information portrayed. A second significant characteristic of ambient displays is that they should make the invisible visible by being informative, aesthetic and usable in a public context.

More recently, ambient displays have been designed to display information not only with the goal of informing but even for potentially influencing people's behavior. Rogers and colleagues (Rogers et al., 2010) have explored the use of ambient displays to influence behavioral change (i.e. whether to take the stairs or the elevator) using subtle and abstract modalities of feedback conveyed through ambient lights and the movements of a decorative sculpture. In a further study, Balaam and colleagues (Balaam, Fitzpatrick, Good, & Harris, 2011) designed an ambient display that could enhance behavioral synchrony by displaying peripheral, subtle feedback about users' nonverbal behavior. These studies showed that the effect of the technology was not always explicitly perceived: the displays indirectly influenced users' nonverbal behavior, while at the same time participants were not aware of this change. The technology subtly influenced people to change their behavior, by using a persuasive strategy similar to behavioral nudging.

In addition to ambient persuasion and interaction, public and group context is another fundamental aspect of ambient intelligence relevant to our work. As for group dynamics, there has been a large amount of research into multimodal support of group conversations and many different attempts have been made to influence group activities providing real-time feedback of the group's social dynamics. Pentland and colleagues (Kim, Hinds, & Pentland, 2012; Pentland, 2010) have developed a system that detects social interactions, such as speech signals and body movements, using sociometric badges, and provides visual feedback on a mobile screen with the aim of enhancing group collaboration in situations where balanced participation and high interactivity are desirable. The system generates feedback visualizations, showing information such as frequency of turn transitions and dominance in the conversation. Such visualizations increase the participants' awareness on their communication patterns and promote cooperative behaviors both in remote and co-located activities (Kim et al., 2012). In the framework of group creativity activities, Tausch and colleagues (Tausch et al, 2014) designed *Groupgarden*, an ambient system that provides graphical feedback about individual and group performance to support brainstorming sessions. The feedback is displayed on a projected screen and is controlled by a facilitator, who is not involved in the group activity. The graphical feedback uses the metaphor of a garden to represent the number of ideas generated by each participant and to emphasize different group dynamics, such as an extremely unbalanced brainstorming session. Even though the system does not automatically assess the group performance, the findings from the deployments of *Groupgarden* give insights on how visual feedback can positively influence brainstorming activities and how technology can support adherence to specific brainstorming rules for ensuring an equal group participation. In a fashion similar to *Groupgarden*, we considered brainstorming as a target activity for ambient influence. However, our goal was to design a system that could operate without the need of a human facilitator, exploring directives and not metaphors as communicative acts for influencing the brainstorming activity.

Different studies have tried to support group activities by giving automated feedback on participants' speaking time. To this end, ambient and peripheral displays were augmented with microphones for automatically capturing vocal activity and generating abstract visualizations of speakers' participation. Such visualizations have the primary goal of increasing and supporting collaborative group activities that take place in the proximity of the technology. In their seminal study, DiMicco and colleagues (DiMicco et al., 2007) investigated the use of ambient displays for visualizing the extent of participation of the members of a small group during a meeting. Each member's participation was measured in terms of vocal activity using close-talk microphones, and was visualized in a shared peripheral display through graphical representations. The visualization had the purpose of stimulating individual reflections on their contribution to the on-going activity and of harnessing social collaboration. The system was evaluated both in real-world situations (e.g. work meetings) and in more structured tasks (e.g. social dilemmas) and it has proven to influence groups behavior towards a more balanced level of participation. A similar approach was adopted in designing *Reflect Table* (Bachour, Kaplan, & Dillenbourg, 2010), an interactive table with a LED board embedded on the surface used to promote balanced participation in a group discussions. The table displays the participant's amount of speech as colored areas on the surface in front of each speaker and it was found to increase awareness of group members about their participation levels.

While the systems mentioned above estimate the participation of each member from their vocal activity, other works have taken into account different behaviors, such as shifts of visual attention between participants. Face-to-face conversation is not just a speech activity between participants, and important information is conveyed also by nonverbal behaviors such as backchannel signals, facial expressions and gaze directions (Gatica-Perez, 2009). The *Relational Cockpit* (Terken & Sturm, 2010) is a system that collects information from vocal and attention behavior cues, such as the attention given to other participants as a listener or the attention received while speaking, and provides participants with dynamic visual feedback on their performance through graphs projected on a table surface. Like the previous example, the *Relational Cockpit* provides participants with more information about the task at hand, presented in the form of feedback visualizations, with the final goal of influencing their attitude and thus promoting a change in their behavior. A different approach was used in the *Museum Café Table* (Zancanaro, Stock, Tomasini, & Pianesi, 2011) a tabletop system that monitors the conversation of museum visitors and dynamically shows visualizations on the table surface. As with the previous examples, this technology gleans information from group conversation with the goal of supporting the social interactions of the members involved in the activity. Yet, instead of displaying feedback visualizations in the form of histograms, colored areas, or a cockpit, the system proactively influences the conversation by providing relevant material for supporting and sustaining the activity as it unfolds. Building on this previous research, the objective of the study presented here is to investigate how an ambient system that monitors user behavior can be used to plan and execute proactive strategies aimed at influencing social interaction in a group conversation.

Tracking Group Behavior

Verbal and non-verbal aspects of the behavior of members of a group provide information on the social dynamics of the group itself, and ambient persuasive technology can be employed to track and gather information from these behaviors. Many investigations have been conducted to explore computational models of social interactions in small groups by analyzing visual and acoustic data (Gatica-Perez, 2009). Studies in multimodal interaction have investigated the relationship between group participation and behavioral indices of visual attention. These studies show that gaze is a good predictor of conversation characteristics such as turn taking, an individual's conversational level of involvement and attention in multiparty conversation (Gatica-Perez, 2009; Vertegaal, Slagter, van der Veer, & Nijholt, 2001). Considering broader aspects of the group activity, visual attention is an important cue to the coordination of social interactions. Behavioral cues, such as mutual gazing, are used by members of a multiparty conversation for signaling communicative intentions and conveying information to the addressee (Vertegaal et al., 2001).

In this work, we focus on a relatively simple analysis of group behavior and estimate group participation through gaze patterns. We thus explore how an ambient display can use this information for influencing group dynamics (specifically by supporting a more balanced participation), enacting subtle ambient persuasion.

Ambient Persuasion

Once the ambient persuasive system has estimated the social dynamics occurring within the group, the system can deploy persuasive messages for influencing group behavior. Different aspects of the persuasive messages can characterize the persuasive strategies enacted by an ambient persuasive system.

Persuasive messages can be overt or subtle. The message is overt whenever it is readily observable or subtle if it is not immediately obvious or comprehensible. The distinction between subtle and overt should be seen more as a continuum rather than two mutually exclusive levels, as proposed in the horizontal axis in Kaptein and colleagues' model of ambient persuasion (Kaptein et al., 2010) suggests. Overt messages, conveyed primarily through written or oral language, require active and conscious processing by the message recipients. When based on structured visual material, such as histograms, they may require conscious reflection on their representations in order to be understood. Contrary to overt messages, subtle messages can be presented in different modalities, e.g. with simple, unstructured visual elements such as images or lights, sounds or tactile stimuli.

Persuasive messages can also be characterized by the way in which their meaning is expressed. A message can have a direct meaning when it overtly expresses the goal of the persuasion strategy. On the opposite side of the continuum, the message might express an indirect meaning when the goal of the persuasive strategy is conveyed in a subtle fashion. Subtle messages are supposed not to distract users from their on-going task: they should not require the processing of voluntary reflection of the recipient nor the full understanding of the message. Subtle and indirect messages represent two important aspects of ambient persuasion.

An additional characteristic has its root in Weiser and Brown's vision of calm technology, specifically in the concept of peripheral interaction. Peripheral interaction takes place in the background or periphery of attention (Bakker, van den Hoven, & Eggen, 2012). Interaction is not exclusively peripheral, but shifts between the center and periphery. In the words of Weiser: "*Calm technology engages both the center and the periphery of our attention, and in fact moves back and forth between the two"* (Weiser & Brown, 1996). Technology, when it does not require full control, should remain in the background, providing information in a calm and unobtrusive manner. A major tenet of our design approach is indeed that technology should never become prominent and distract users from their intellectual and social activity.

In designing persuasive strategies for ambient persuasive systems, attention should be devoted not only to the way in which the message is conveyed, but also to how the message content is expressed. As it has emerged from related research, feedback and recommendations are one way of communicating information about group activity to the group itself.

Feedback is defined as any information regarding an aspect of one's performance in a past or on-going activity, provided to increase awareness or to influence the activity in the present or in the future (Hattie & Timperley, 2007). Technology-mediated feedback encompasses any feedback mediated by technological devices that has the goal of helping users monitor and reflect upon their behavior. Feedback visualizations provide a tool to the group members for adjusting their behavior by increasing awareness on aspects of the activity at hand. Examples of feedback strategies are the use of histograms (DiMicco et al., 2007), colored areas (Bachour et al., 2010; DiMicco et al., 2007), or a cockpit (Terken & Sturm, 2010). In order to have feedback messages that actually influence behavior, receivers need to understand how their performance influences the feedback representation and what the meaning of the feedback itself is. Beside feedback, recommendations are another common strategy for influencing behavior through advice and suggestions. Recommendations are usually presented with direct language and text, and they require attentional resources from the receiver to be fully understood.

In the context of Searle's Theory of Speech Acts, those recommendations can be categorized as "*directives*", communicative acts that have the explicit intention to induce the receiver to perform a certain action (Searle, 1976). Directives are attempts to obtain a change in the state of the world by intervening with a message on other individuals. Directives might differ by the force of the attempt (Thomas, 1995): directive acts might include threatening acts, such as requests and orders, and more non-assertive acts including suggestions and instructions. On the other hand, feedback messages represent a different type of illocutionary speech act. Using Searle's terminology, feedback is an assertive illocutionary act (i.e. it is intended to communicate a state in the world), yet, in a persuasive system, it is often intended to induce the receiver to perform an action in a fashion similar to a directive (indirect speech acts). Feedback messages rely in fact on mutually shared background information between the speakers, and require inference on the part of the receiver in order to be fully understood. They represent a particular situation, without providing the recipient direct indications to change the situation. Thus, feedback messages possess a different illocutionary force compared to recommendations.

In the present study, we investigate the use of a hybrid form of directive, combining the benefits of subtle communication such as feedback visualizations with the illocutionary force of recommendations.

Our Approach: Persuasion for Immediate Group Behavior Changes

Our goal is to influence the group toward immediate micro-changes in individual behavior that will eventually lead to a more effective group interaction. In this respect, we adopt the stance of the Nudge Theory (Thaler & Sunstein, 2008) by providing indirect suggestions to achieve immediate behavior change, rather than explicitly targeting the attitude of the participants and their long-term behavior (as described in the Theory of Planned Behavior; Ajzen, 1991).

Our persuasive strategies were inspired by one of the key functions of group facilitators, as mentioned above, namely to "ensuring that all team members contribute" (Burns, 1995). The aim of our persuasive technology is to make the group conversation as balanced as possible, guiding participant attention by using peripheral visual messages. The resulting ambient persuasive system is meant to influence and modify group behavior without being the primary focus of the participants' activity and thus influencing through indirect means rather than through explicit feedback visualizations or recommendations.

We draw on concepts from philosophy of language (Searle, 1976) and social psychology to characterize the design of multi-user interfaces that provide information that can be used to support group activity and to influence social dynamics. The prototype represents an example of ambient persuasive technology (Kaptein et al.,

2010) where behavior change is promoted through social influence and achieved with minimal obtrusiveness (excluding coercion or deception).

Design and Implementation

This section presents the design objectives that guided the development of our ambient persuasive system, and outlines the specific choices for the design of the final prototype. The design pursued the following objectives:

- the aim of the system is to influence group dynamics, specifically to lead the group toward a more balanced participation during brainstorming activities;
- the system should deploy non-verbal directives through peripheral visualizations for influencing group dynamics, with minimal interference with the focus of the group activity;
- sensors should be employed to monitor the group context in order to provide targeted messages at the appropriate time.

Also, the system has features such that would allow it to be deployed in everyday contexts, therefore the prototype was developed using minimally invasive hardware: in particular, we chose ambient sensors (i.e. camera-based sensors) rather than wearable devices (e.g. close-talk microphones or biometric devices).

After pilot studies (not described here), we decided to employ an animation of colored bubbles as an appropriate way to convey a message to the peripheral attention of a user. The direction of the bubble flow had the purpose of inviting participants to turn their attention in that direction (for more details see “The Visual Intervention” section).

Our system differs from other approaches both for the low level of technology invasiveness and for the persuasive strategies adopted. In particular, rather than using graphical representations that reflect the progress of the conversation, and inducing behavior change through awareness, we chose to adopt a proactive strategy by means of a system that will suggest a certain behavior to users.

Design Proposal

The main design objective was to provide a system able to blend into the environment and to fit in a brainstorming setting. Kinect sensors were chosen as a simple and effective tool for tracking group behavior. We therefore needed to design a piece of furniture to accommodate the Kinects as well as the displays for directive visualization.

Initial pilot studies showed some critical challenges regarding the robustness of signal tracking when using Kinect sensors with group of people. Therefore, we decided to limit the number of participants to four and to rearrange the setting by placing one chair in front of each Kinect (Figure 1). These constraints will eventually be removed for a real-life application but, at present, they allow us to have reasonably good accuracy in the monitoring of behaviors.

A further design objective was to provide a system that could be easily deployed in any environment. To this end, we decided to avoid locating cameras and microphones in the environment and we tried to include both the sensors and the displays in a single, portable object. As for its appearance, we decided to design an object that looks like an adornment for a small table that can be placed in the middle of the group of discussants.

In exploring the design space, we drew inspiration from tiled displays (e.g. *Pinch* (Ohta & Tanaka, 2012) and *Siftable* (Merrill, Kalanithi, & Maes, 2007)) and considered different arrangements of the displays on the table in order to explore the different possibilities for showing information with a higher or lower levels of publicness. We decided on a dome-like shape, since we deemed it the most suitable shape for pursuing our design goals (Figure 1). Placing four displays orthogonally on the surface of the dome, allows to provide personal spaces for visualizing messages while the top part can accommodate the Kinect sensors at a suitable height. At the same time, this shape could also accommodate a shared display for testing shared information visualizations.

Prototype Design

Four 10-inch cardboard frames were cut out so that only the tablet screens would show and the tablets would be embedded within the prototype. The frame surfaces were adjusted with an inclination of about 30 degrees in order to optimize display view. An upper base was also built to contain the four Kinect sensors placed orthogonally. Finally, a cover made of the same materials of the container was placed on top of the Kinect sensors to give the impression of a single piece of furniture.

Figure 1. Prototype Design

Technology and Scene Analysis

The system monitors group members' non-verbal behavior through Kinect sensors uses this information to estimate their participation and purposefully intervene in the dynamics of the group.

Each Kinect camera analyzes one participant by detecting the position of their head and tracking who she/he is looking at, by using an algorithm that considers the relative positions of the other participants in the setting (for a complete description of the algorithm see Schiavo, Cappelletti, Mencarini, Stock, & Zancanaro, 2014a). The focus of attention is automatically estimated by assessing whether each person's head is directed toward the participant on the left, on the right, directly opposite, or toward no one in particular. The latter case denotes the state where the person is not looking at other members (e.g. the target is looking down at the table). The positions of the chairs were fixed and the horizontal angle used to discriminate between left, front and right was set at 35°. These values were based on previous studies in the literature (Terken & Sturm, 2010).

The Visual Intervention

The persuasive interventions are conveyed on the peripheral displays in the form of subtle or overt directives with the intended aim of inducing balanced group participation. The system targets specific participants based on the group behavior and gives targeted directives to all participants.

The default ambient display is a neutral state, showing an animation of a few colored bubbles moving randomly at low speed. If the system considers the conversation balanced, this state will be maintained. The neutral visualization was designed to show that the system is still active and that it does not require focal attention from the participants.

When the system detects inequality in participation, a group member with low participation is selected as the target of the communication strategy (Figure 2). The visual intervention is implemented as follows:

- For the selected participant, the bubbles start moving in a circular way;
- For the other participants, on their respective displays, the bubbles start aligning and moving toward the target participant;
- The animation continues until the system detects balanced participation. The system continuously analyzes the group dynamics and changes the target of the intervention if needed.

In order to compare the subtle strategy with a language-based intervention, we implemented an overt communication strategy as follows:

- The selected participant sees one of the following textual messages (randomly selected to avoid repetition) on the display: “Come on! You too can contribute”, “You’re not participating enough! Say something!” and “What do you think about that?”;
- Each of the other participants sees on his/her display one of the following messages (randomly selected as well): “You should include everyone in the conversation!” “Maybe the person in the [red/green/yellow/violet] chair wants to say something!”, “What does the person in the [red/green/yellow/violet] chair think?”.

The text appears on the screen as an animation, remaining visible for 20 seconds before fading out. As in the previous strategy, the group situation is continuously assessed.

Evaluation

Two studies explored how ambient persuasive systems can influence group dynamics in group brainstorming sessions. The first study investigated the use of the directive approach implemented through a subtle, non-distracting and pleasant animations versus an overt, language-based approach. The second study, building on the findings of the first one, investigates the effects of publicly showing the information to the entire group by displaying directives on a shared screen and compares the effects of subtle and overt directives. This is a first step to understanding the potential use of illocutionary acts for non-verbal and subtle persuasive peripheral visualizations.

Hypothesis

For both studies, we formulated the following hypotheses concerning the influence of ambient system on social dynamics:

H1. Participants exposed to the subtle directives will engage in more balanced gaze patterns than participants who are exposed to the overt directives, in particular when the participants understand the meaning of the visualizations;
H2. Participants exposed to the subtle directives will be more satisfied and less distracted by the system than participants who are exposed to the overt directives;
H3. Participant satisfaction and group cohesion will be higher with subtle visualizations;
H4. Participants who do not have information on the meaning of visualizations will be influenced by the system without subjectively perceiving the persuasion.

The hypotheses were investigated in Study 1 during the deployment of a first version of the prototype in a real-world scenario, while Study 2 investigated the same questions evaluating a further iteration of the prototype in a more tightly controlled setting.

Experimental Design

The studies used a between-subject design with one independent variable – the type of directive. The three conditions were (Table 1):

- *Subtle directives* (S). In this condition the system displays the peripheral subtle animation for influencing the group (as presented in the previous section). In order to investigate the impact of explaining the meaning of the animation we considered two conditions:
    - *Subtle directives with explanation* (S+). In this condition the group was informed before starting the task about the behavior of the system and the meaning of the visualizations.
    - *Subtle directives without any explanation* (S-). The system used subtle visual

directives, but the group did not receive any explanation on their meaning prior to the session.

- *Overt directives* (O). The system showed directives in the form of text. This condition was designed to exploit the use of a language-based persuasive strategy.

Table 1. Experimental conditions in the two studies

Study 1

The first study investigated the effectiveness and acceptability of two types of personal messages aimed at balancing the participation within the group (Schiavo et al., 2014a). Objective and subjective metrics of performance and participation were collected in a real-world setting. Specifically, the study was conducted in the premises of a science museum where participants were asked to participate in a brainstorming session using the prototype. We compared the effect of overt, language-based directives versus subtle, graphical visualizations. The dependent variables were: (i) quantitative information on group attention behavior gathered through the analysis of gaze patterns recorded with the Kinect sensors, and (ii) reported extents of intrusiveness and usefulness collected through questionnaires and group interviews (Table 2). In the prototype used in the first study, each tablet display acted as a personal ambient display since it was meant to be visible only to the person in front of it (Figure 2).

Table 2. Dependent variables and instruments used in Study 1

Figure 2. Study 1 Setting (A) and Diagrams of the Subtle Strategy: Normal state (B) and Directive state (C)

Participants

15 groups of four people, for a total of 60 participants (39 females), were recruited

among passers-by from a social event held at the local science museum. The participants were aged between 18 and 60, and none of them had previous experience with the prototype. Both acquainted and unacquainted individuals and same- and mixed-gender groups were involved in this study: the museum setting did not allow for the experimental control of these factors.

Procedure

Participants were asked to brainstorm ideas for 10 minutes on how to improve ecological practices in daily life, such as, reducing waste and improving sustainability. The topic of sustainability fitted well into the museum setting and was coherent with the theme of the specific event in which the study was located. Before taking part in the brainstorming session, participants were informed that the system was able to track data from their nonverbal behavior (i.e. gaze patterns) through the Kinect sensors and signed a consent form. At the end of the study session, they received full information on the experimental conditions and on the goal of the study. Although the participants were informed about the nature and the objectives of the study, this setting made it more natural and less "lab-based". Yet, it also limited the control we had on the experimental variables and the quality and range of data that could be collected.

Dependent Variables

Group attention behavior. The data from sensor logs were collected maintaining anonymity and subsequently analyzed. In order to measure the group attention behavior patterns, we estimated the equality of the distribution of attention at the group level by defining a Balanced Attention Index (BAI). BAI was calculated as the sum, over all the group members, of the deviation of each member's attention from an equal distribution, normalized by the maximum possible value of the deviation. The index was inspired by the Gini coefficient, a measure of equality often used in non-verbal behavior research: for instance, similar metrics had already been adopted for measuring participation equality in group conversations using speaking time and visual attention (Terken & Sturm, 2010).

Questionnaires & Group Interviews. Subjective judgments about individual attitudes toward the system were collected by means of questionnaires. We used 10 items to investigate the experience and the perceived disturbance of the system (see Table 3). Perceived cohesiveness of the group has been measured through an adapted version of the Price and Muller Work Group Cohesion Index (5 items). The semi-structured group interviews addressed specific topics, such as perceived reliability of the system, benefits and drawbacks of the ambient messages and personal concerns.

Results

Balanced Attention Index. The Balanced Attention Index (BAI) represents to what extent the amount of attention received by each participant is equally distributed (Figure 3). The index ranges between 0 (unequal distribution) and 1 (equal distribution): the more the distribution of attention deviates from an equal distribution; the lower is the resulting index (for a detailed description of the Balanced Attention Index see Schiavo et al, 2014a). On average, BAI index was high in S+ ($M = 0.79$) with a peak in the first half of the sessions, while in the other two conditions it remained relatively stable across time intervals (S- & O, both $M = 0.72$). Even though the pattern was in the expected direction, a one-way ANOVA did not reveal any statistically significant difference between conditions ($p > .05$).

Figure 3. Average values of the Balanced Attention Index by conditions at different session times.

Questionnaires. According to questionnaires (Table 3), participants were satisfied with the number of ideas they produced during the brainstorming session (*M* = 3.00, *SD* = 0.80) and with the group work (*M* = 3.80, *SD* = 0.80). All the groups reported high scores on the cohesion dimension (*M*= 4.08, *SD*= 0.57; Cronbach's alpha for this scale was 0.81). Regarding the intrusiveness of the system, participants were not disturbed by the presence of the Kinect cameras (*M* = 1.58, *SD* = 0.91) and generally reported that the displays were slightly distracting (*M* = 2.20, *SD* = 1.11), but no significant differences across conditions were observed (one-way ANOVA, $p > .05$).

One-way ANOVA indicates a statistically significant difference in the scores on the perceived usefulness of the system for the three conditions ($F_{2,57} = 23.86$, $p < .01$, $r = .66$). Participants exposed to the subtle intervention with prior explanation (S+) perceived the system as more useful compared to participants in the other two conditions (both $p < .01$). Moreover, participants in S+ condition reported that the system had stronger ($F_{2,57} = 5.60$, $p < .01$; $r = .41$) and more positive ($F_{2,57} = 6.1$, $p < .01$, $r = .42$) influence on the discussion compared to S- ($p < .01$), but no significant differences were observed compared to overt messages ($p > .05$).

Table 3. Responses to the questionnaire (means and standard deviations) and ANOVA results. Items are on a 5-point Likert scale from 1 (Not at all) to 5 (Very much). N=60.

Group interviews. The interviews helped to clarify the answers to the questionnaires. Participants in *S*- condition reported that they actually noticed that the animation changed over time, but they tended to ignore the displays since they were not able to give any meaning to the animations. As a result, most participants in this condition regarded the system and its intervention as meaningless and uninteresting.

In O condition, participants understood that the purpose of the system was to include everyone in the conversation but they also found that the displayed messages were distracting and intrusive.

Considering *S+*, some participants actively used the display to monitor the conversation, following the direction and the color of the animation to adjust their behavior accordingly. Yet, some other participants felt uncomfortable with the system since it could publicly reveal their under-participation. Participants, however, indicated that the animation adequately represented the group dynamics, although they did not devote their attention to the displays continuously.

Study 2

The first study provides evidence that subtle directives are not less effective, but definitely more acceptable and less obtrusive than overt directive messages. However, information was provided individually through personal displays and we did not investigate the effect of a complete disclosure of the information to the whole group through a shared display. The large variation of feelings and attitudes expressed by the participants with regards to the system and its purposes may suggest that people with different personality traits perceive system intervention differently. This is an interesting aspect that might impact the acceptability of ambient persuasive systems. A subsequent study was then conducted in a more controlled setting for investigating the use of a shared display and the effects of personality traits on subjective judgments (preliminary results of this study were presented by Schiavo et al., 2014b).

In the second study, the prototype was augmented with a shared display and all three conditions of Study 1 were tested. The shared display (17-inch 4:3 LCD screen) was located horizontally on the top of the structure that held the 4 personal displays and it was used to provide a shared view on the animation in the "subtle" conditions, and on the suggestions for turn-taking in the "overt" condition. Specifically, the subtle animation was designed as a flow of bubbles that moved from the tablet screens to the shared display, using the movement direction to target a specific participant. In the neutral state, the animation shows few bubbles slowly moving without a direction (Figure 4). For the overt intervention, the same language-base directives used in Study 1 were presented in the personal displays, while the shared screen showed an arrow pointing toward the target participant. The use of a shared screen for displaying information to the whole group made the use of color to indicate the participants in the subtle animation and in the overt sentences not necessary anymore. The color palette for the animation was chosen to improve visibility of the animation in the shared display.

Figure 4. Study 2 Setting (A) and Diagrams of the Subtle Strategy: Neutral state (B) and Directive state (C)

Participants

12 groups, for a total of 48 participants (23 females and 25 males), were involved in the second study. Participants were aged between 26 and 56 and were affiliated to an IT research center in Italy. None of them had previous experience with the system but all had prior experience in brainstorming. Participants were recruited via e-mail and groups of mixed gender were formed by selecting volunteers from different departments. Once the groups were formed, they were randomly assigned to one of the three experimental conditions (resulting in 4 groups for each condition).

We asked participants to rate how well they knew each other group members (in a 5-point Likert scale, with 1 "not at all" and 5 "very well"). Overall, participants reported on average middle scores on the scale (M = 2.6, SD =1.1), and no differences between groups for the three conditions were found (O: M = 2.6, SD = 0.9; S-: M = 2.4, SD = 1.4; S+: M = 2.7, SD = 1.3; one-way ANOVA, $F_{2,45}$ = 0.24, p > .05).

Procedure

After completing a consent form (similar to the one used in the first study), participants were asked to brainstorm ideas on how to improve their workplace cafeteria service for 15 minutes. We decided to change the brainstorming topic from Study 1 in order to promote discussions on a specific issue that could personally interest the participants. After the brainstorming session, they were asked to fill questionnaires and were also informed about the experimental conditions and the goal of the study.

Dependent Variables

This second study was conducted in a more tightly controlled setting which allowed the collection of a wider set of dependent variables compared to the first study (Table 4).

Table 4. Dependent variables and instruments used in Study 2

Ideas from each brainstorming session were recorded and coded in order to measure brainstorming performance in terms of number, originality, and feasibility of ideas. As in the previous study, the Balanced Attention Index was used as a measure of balanced participation but a more detailed analysis of gaze patterns was performed. The previous individual questionnaire exploring users' experience with the system and their perceived cohesiveness of the group was used. Moreover, participants were asked to fill out the AttrakDiff questionnaire (Hassenzahl, 2001), which assesses the pragmatic, hedonic and appealing attributes of the technology. The AttrakDiff questionnaire was used to further explore the perceived qualities of the system and to discriminate between pragmatic and hedonic qualities. Lastly, we asked participants to respond to a short personality inventory (BFI -10, Rammstedt & John, 2007) for collecting information on their personality traits. Many studies have shown that personality characteristics of the target affect the effectiveness of persuasion strategies: individuals with different personalities are more likely to be influenced by specific persuasive messages (Perloff, 2003; Hirsh, Kang, & Bodenhausen, 2012). Persuasive messages are in fact more effective when they are tailored to reflect the recipients' personality profile (Hirsh et al., 2012). Psychological constructs such as the need for cognition, self-monitoring tendency, dogmatism and others have been studied as important personality variables that mediate and influence persuasion processes (Perloff, 2003). In our analysis we relied on one of the most used framework for conceptualizing personality traits: the Big Five Model (Goldberg, 1990). Each of the five personality dimensions reflects a set of different motivational systems that might influence the outcome of a persuasive strategy. For example, extravert individuals are more sensitive to rewards and social attention, conscientious people are especially sensitive to order and efficiency, while open-minded individuals value creativity and intellectual stimulation (Hirsh et al., 2012). In order to limit the overall duration of the study, we used the BFI-10, a 10-item survey with acceptable levels of reliability and validity compared to full-length personality inventories (Rammstedt & John, 2007).

Results

Brainstorming performance. To evaluate brainstorming performance we used a methodology frequently applied in problem solving research (Paulus et al., 2002) consisting in transcribing the ideas and having judges rate feasibility and originality of each idea. The ideas from the brainstorming sessions were recorded and combined in a list containing a total of 91 ideas. In order to avoid repetition and similar ideas, the list was further narrowed down to 41 ideas. For instance, the idea of "extending the cafeteria open hours by 30 minutes" and the idea "calling for more flexible cafeteria open hours" were combined in "extending the cafeteria opening time". *Originality* and *feasibility* were measured on a 3-point Likert scale were 3 is the highest score. An idea scored high in *originality* if it was creative and unique. A high score on *feasibility* was given to ideas that were thought to be practical and realistic. 10 judges rated each one of the 41 ideas listed. Inter-rater reliability was estimated using Intra-class Correlation Coefficient (Two-Way Random ICC): for *originality* and *feasibility* scores ICC values indicate good inter-rater agreement (Hallgren, 2012): ICC(41,10) = .74 and ICC(41,10) = .84 respectively, where ICC value of 1 indicates perfect agreement and 0 random agreement. Weighted average scores were calculated for each idea based on the number of ratings at each point of the Likert scale. Correlation between originality and feasibility was significant ($r = .40$, $p < .01$). Originality and feasibility scores were analyzed by means of Kruskal-Wallis test, but no significant differences were observed between the three conditions ($p > .05$). Table 5 reports a summary of performance measures across the experimental conditions.

Table 5. Mean values and standard deviations of brainstorming performance measures

Attention and Gaze behavior. Similarly to Study 1, we analyzed patterns of the Balanced Attention Index across conditions. For the S+ and the O conditions, BAI was almost stable across session quartiles with an average value of .74 (*SD* = .14) and .84 (*SD* = .06) respectively. The overall average of the index for the S- condition was .54 (*SD* = .19), stable for the first three quartiles of the sessions and with a peak at the end of the sessions (Figure 5). These values were similar to those observed in Study 1. The analysis indicated a difference between the three conditions for the second quartile, corresponding to the 50% of the session time (Kruskal-Wallis test: $H = 6.04$, $p < .05$). Mann-Whitney tests (with Bonferroni correction) showed that values for O and S- conditions were significantly different ($z = -2.3$, $p < .01$, $r = .66$), suggesting that attention in groups were more balanced in the “overt” condition compared to the “subtle” condition without explanation.

Figure 5. Average values of the Balanced Attention Index by conditions at different session times.

A more in-depth analysis of gaze patterns was performed, to assess whether the system had influenced the group gaze behavior. Specifically, we expected an increased gaze time toward the under-participating target after the graphical intervention had been triggered on the display.

From the system log file, we considered all the events in which the strategy was activated. A total of 333 strategy activations were observed (88 for the O condition, 131 for S+ and 114 for S-). For each strategy activation, we analyzed gaze time directed toward the target of the strategy 20 seconds before the enactment of the visual intervention and three time intervals afterwards (respectively 10, 15 and 20 seconds).

A repeated-measures ANOVA was performed with factors *Time* and *Condition* (as between subject factor). The analysis indicated a significant effect of *Time* factor ($F_{3,987} = 16.41$, $p < .01$, $r = .22$). No interaction between the two factors was observed.

Contrasts revealed that the gaze time directed toward the target after 15 ($F_{1,329} = 10.65$, $p < .01$; $r = .18$) and 20 seconds ($F_{1,329} = 17.80$, $p < .01$, $r = .23$) after the enactment of the strategy were higher compared to the same metric measured in the previous 20-second interval. Post-hoc tests adjusted with Bonferroni correction showed that the differences are statistically significant for each of the three conditions ($p < .01$).

In order to normalize the data for the different time intervals, percentages of gaze time were calculated for each time window based on the following calculation: the gaze time directed toward the target divided by the total gaze time directed toward any member of the group. The average measures across conditions are shown in Figure 6.

Figure 6. Percentage of gaze time

Similarly to the previous analysis, a repeated-measures ANOVA with *Time* and *Condition* factors was conducted. The main effect of the *Time* factor was significant ($F_{3,987}$=12.78; p<.01; r=.19), contrasts revealed that the percentage of gaze toward the target increased from pre-time (before strategy enactment) to post time after 10 seconds ($F_{1,329}$ = 10.96, p < .01, r = .18), 15 seconds ($F_{1,329}$ = 14.9, p < .01, r=.21) and 20 seconds ($F_{1,329}$ = 18.33, p <. 01, r = .23). Post-hoc analysis adjusted with Bonferroni correction showed a significant difference for all conditions (all p < .01).

Further analysis was performed to assess whether the ambient system could also exhibit global efficacy, which is the effect of balancing the overall gaze behavior of the group. A global efficacy score was calculated as the arithmetic difference between gaze times directed toward the most-looked-at member and the gaze times directed toward the least-looked-at one. The score is subtracted from 1, so the resulting index is close to 1 when the difference is small since the gaze time is shared among member in a roughly equal manner. It is close to 0 when only one member is looked at for the entire time interval. A repeated-measures ANOVA (with factors *Time* and *Condition*) revealed a statistically significant interaction between *Time* and *Condition* ($F_{6,990}$ = 2.89, p < .01, r = .13), and a significant effect of *Time* ($F_{3,990}$ = 19.28, p < .01, r = .23) and *Condition* ($F_{2,330}$ = 14.76, p < .01, r = .29) for the global efficacy index.

As shown in Figure 7, both local and global efficacy were observed for 55% of strategy activations, meaning that generally the persuasive strategy led not only to increased gaze time toward the target (local efficacy), but also to a more balanced distribution of gazes among group participants (global efficacy). Moreover, there was a positive correlation between local and global efficacy considering pre-post intervention differences (*Pearson's* r = .24, n = 333, p < .01).

Figure 7. Strategy activations categorized by local and global efficacy.

Questionnaires. Regarding the perceived usefulness of the system, a one-way ANOVA revealed a statistically significant difference in the scores across the three conditions (Table 6). Post-hoc pairwise comparisons (Tukey's HSD correction) indicated that participants in the O condition perceived the system as more useful compared to the S- condition ($p <. 01$), but no differences were observed with respect to S+ condition. Consistently with the pattern of visual attention, participants in the O condition reported that the system had stronger influence compared to participants in the other two conditions ($p <. 05$). Nevertheless, participants in the O condition found the displays to be more distracting compared to the participants in S+ and S- conditions (both $p <. 05$). Finally, Group Cohesion Index (Cronbach's alpha = .77) was slightly lower when participants were exposed to subtle directives without explanation ($p <. 05$).

The AttrakDiff scales demonstrated good reliability: "pragmatic qualities" scale (Cronbach's alphas = .78), "hedonic qualities" scale (Cronbach's alphas of .75) and "appeal" scale (Cronbach's alpha = .85). A one-way ANOVA showed a statistical significant difference across conditions for responses on the "pragmatic qualities" and "appeal" scales, but no differences on the "hedonic qualities" scale (Table 6). Post-hoc pairwise comparisons (Tukey's HSD correction) showed that the system was perceived as less pragmatic with subtle directives without explanation compared to the other conditions (S- vs. O: $p <. 01$, S- vs. S+ $p <. 05$). These results suggest that in S-, the users perceived the system as useless or meaningless. In S+, the system was rated as more appealing compared to the other two conditions (S+ vs. S-: $p < .01$, S+ vs. O: $p < .05$).

Table 6. Responses to the questionnaire (means and standard deviations) and ANOVA results. Items are on a 5-point Likert scale, while AttrakDiff scales are based on 7-point scale items. N=48

Personality influence. In the "overt" condition, we observed that extraversion scores negatively correlated with opinions regarding usefulness and the influence power of the technology (Pearson's $r = -.69$, $p < .01$ for "*I found the information displayed useful*", and $r = -.52$, $p < .01$ for "*I think the system had an influence on the discussion*"). In the "subtle" conditions, the conscientiousness trait (that is the tendency to show self-discipline and to prefer planned rather than spontaneous behavior) negatively correlated with scores on the question "*I think the system had an influence on the discussion*" (S+: $r = -.68$, $p <. 01$, S-: $r = -.52$, $p < .01$). The results suggested that the overt system was mostly accepted by participants with low extraversion score, while the subtle version was considered more influential for people with low scores on consciousness trait.

Discussion

The results from the two studies suggest that the approach of subtle targeted directives provided in an aesthetically appealing and unobtrusive manner might be an effective way for nudging participant's behavior and influencing group dynamics. The findings show some evidence that subtle directives may be as effective as the overt messages to support balanced participation, provided that participants have a prior understanding of the meaning of the former (as described in H1). Evidence of this is shown by the improvement of the Gini-like distribution of the visual attention in Study 1 for the subtle directives with explanation condition. Unlike this, in the other two conditions the distributions of visual attention do not show any balance improvement. Subjective measures as per questionnaires and post-task interviews indicate that this lack of improvement might be due to two reasons: the subtle directives without explanation tend to be considered meaningless and uninteresting while language-based messages are distracting and obtrusive. In Study 2 we further assessed the system efficacy both locally and globally. We found that the system influenced the group gaze behavior, successfully directing more attention toward the target of the strategy (local efficacy) and balancing the gaze time shared among participants (global efficacy). Local efficacy was observed for all conditions, while global efficacy was more pronounced in the "overt" condition compared to the "subtle" ones.

Questionnaire responses from Study 2 confirmed that the subtle intervention with explanation was perceived as more appealing than the other two (H2). The concept of appeal refers to a subjective attribute on the technological device that combines perceived pragmatic and hedonic qualities into a single global judgment (Hassenzahl, 2001). While the condition with subtle directives without explanation scored lower in the pragmatic scale compared to the other two conditions, the subtle intervention with explanation received rates similar to the overt one on pragmatic and hedonic scales, scoring higher on the appeal scale. These results may suggest that the subtle intervention when explained is similar to the overt strategy in terms of functionality and perceived influence. Moreover, post-task interviews from Study 1 and questionnaires from Study 2 support the hypothesis that subtle intervention was considered less distracting compared to overt messages. Adding a shared display in the second study might have increased the feelings of being distracted by the screens, especially for the groups in the "overt" condition. A good level of perceived functionality and its peripherality might thus explain the higher scores on the appeal scale, confirming our second hypothesis.

Regarding the possible effect of the ambient persuasive system on group cohesion scores (H3), results from Study 1 did not indicate any difference in the Price and Muller’s Index across conditions. Values were on average high, suggesting good perceived cohesion in all the three conditions. A difference emerged in Study 2 where the subtle intervention without explanation reached lower scores compared to the other two interventions: groups perceived lower level of cohesion, while the system received almost no attention at all. This finding might suggest that participants’ perception of group cohesion was affected by the shared information. Moreover, the cohesion index was higher for Study 2 compared to Study 1 (Mann-Whitney: $U = 1100$, $Z = -2.12$, $p < .05$). This might be explained either by the use of the shared display or by the different populations involved in the two studies (participants experienced in brainstorming activities in Study 2 versus passers-by from a more heterogeneous population in Study 1).

Lastly*,* we formulated the tentative hypothesis that participants would be nudged toward a more balanced participation by subtle intervention, even when unaware of the meaning of the subtle animation (H4). This would have a similar effect of ambient influence as found in related works (Balaam et al., 2011; Rogers et al., 2010). Findings from Study 1 do not support this hypothesis. Patterns of Balanced Attention Index for the subtle intervention without explanation were less balanced compared to the other two conditions. Moreover, results from questionnaires and group interviews indicate that the participants generally regarded the ambient system meaningless and uninteresting. A possible explanation could be that since participants did not understand the meaning of the subtle animation when the meaning was not explained, they completely disregarded the displays shortly after engaging in the discussion. However, in Study 2 we observed that local and global efficacy increased after strategy enactment for all the conditions: these results were expected for the overt messages and the explained subtle directives, but not for the subtle intervention without explanation. The influence on the group attention behavior is somehow in contrast with the questionnaire results: even though participants found the system useless, their behavior was influenced by the ambient visualization.

Conclusion

In this paper, we presented a novel approach to subtle persuasion for groups of people involved in brainstorming sessions, framed in the context of the Nudge Theory and the Ambient Intelligence paradigm.

We discussed the design of an ambient persuasive system for monitoring group behavior and influencing group dynamics by means of real-time directives. The system tracks non-verbal behavioral cues and estimates group attention patterns for planning its persuasive interventions. Specifically, the ambient system provides directives in the form of subtle persuasive peripheral visualizations. The results of a between-subject evaluation show that the participants gave positive feedback about the function of the messages provided by the system, regardless of the fact that the directives were shown on personal displays or on a shared screen. Lastly, the correlation between perceived usefulness and personality traits suggests that participants who scored low on extroversion and consciousness evaluated the system more positively. Combining this evidence with the findings from the interviews of Study 1, we can hypothesize that the ambient persuasive system was better accepted by participants who tended to be introverts (with low scores on the extraversion scale), and probably less involved in the discussion. Yet, it also emerged from interviews that publicly disclosing under-participation of group members could negatively affect the overall acceptability of the persuasive system. Further research is needed to explore the relationship between personality differences and ambient persuasion, and the resulting ethical implications (Kaptein & Eckles, 2010).

The constraints on the design of this ambient persuasive system have imposed some limitations on the generalization of the outcomes. The prototype is actually limited to tracking information from four users. While 4-user groups have been studied in similar works, the rather low number of participants might have affected the group dynamics. Furthermore, the monitoring capabilities of our prototype were limited to non-verbal visual attention: improvements toward more comprehensive monitoring of group behavior are advisable. Finally, we tested only a single communication strategy (the use of directives) with a single modality of interaction at a time (either written text or visual animation). Future research is required to investigate the effect of different persuasive strategies and the use of multiple modalities in conveying subtle directives.

Although still not conclusive, the findings suggest that subtle directives may effectively change the social dynamics in a small group of people. This approach represents a different stance with respect to the common use of awareness feedback systems. In our case, the system provides illocutionary directive messages intended to induce recipients to perform a certain action. The illocutionary force of a communicative act stems from the intention of the message originator to change the state of affairs by intervening (linguistically, in the original concept) on another agent. A condition is that the message originator be confident that their expression will be recognized as a communicative message, and that the recipient have the means to understanding it (e.g. lexicon, grammar). The results of the study showed that participants' attentional behavior was influenced when the message was unambiguous (overt directives), when the participants had the means to understand the persuasive intent (subtle directives with prior explanation) and, also, when the messages were conveyed in a complete subtle manner (subtle directives without explanation). However, participants' attitude toward the group activity was mainly influenced when the meaning of the message was conveyed through overt messages or provided beforehand in the subtle intervention. The study suggests that having at least a basic understanding of the meaning of the subtle directives is a crucial factor in determining the persuasive effect of the ambient device. Future investigations might explore visualization strategies and techniques that do not require explicit explanations.

Concluding, the current findings provide insight on the effect, the acceptability and the perceived influence of subtle peripheral persuasive messages for ambient displays. The broader implication of this research is that subtle ambient messages lead to an adjustment of participation behavior if their intent is understood. Subtle, peripheral and aesthetically pleasant directives are more effective and appealing compared to overt directives.

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Figure List

Table List

Figure 1. The prototype design process: initial prototype (left), structure (middle) and final setting (right)

Figure 2. Study 1 Setting (A) and Diagrams of the Subtle Strategy: Normal state (B) and Directive state (C)

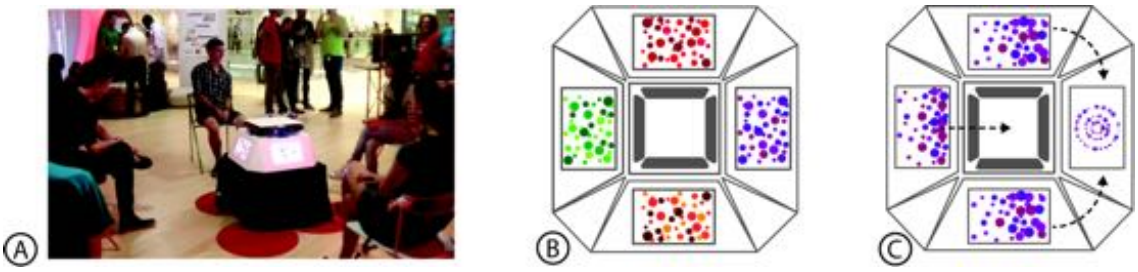

Figure 3. Average values of the Balanced Attention Index by conditions at different session times.

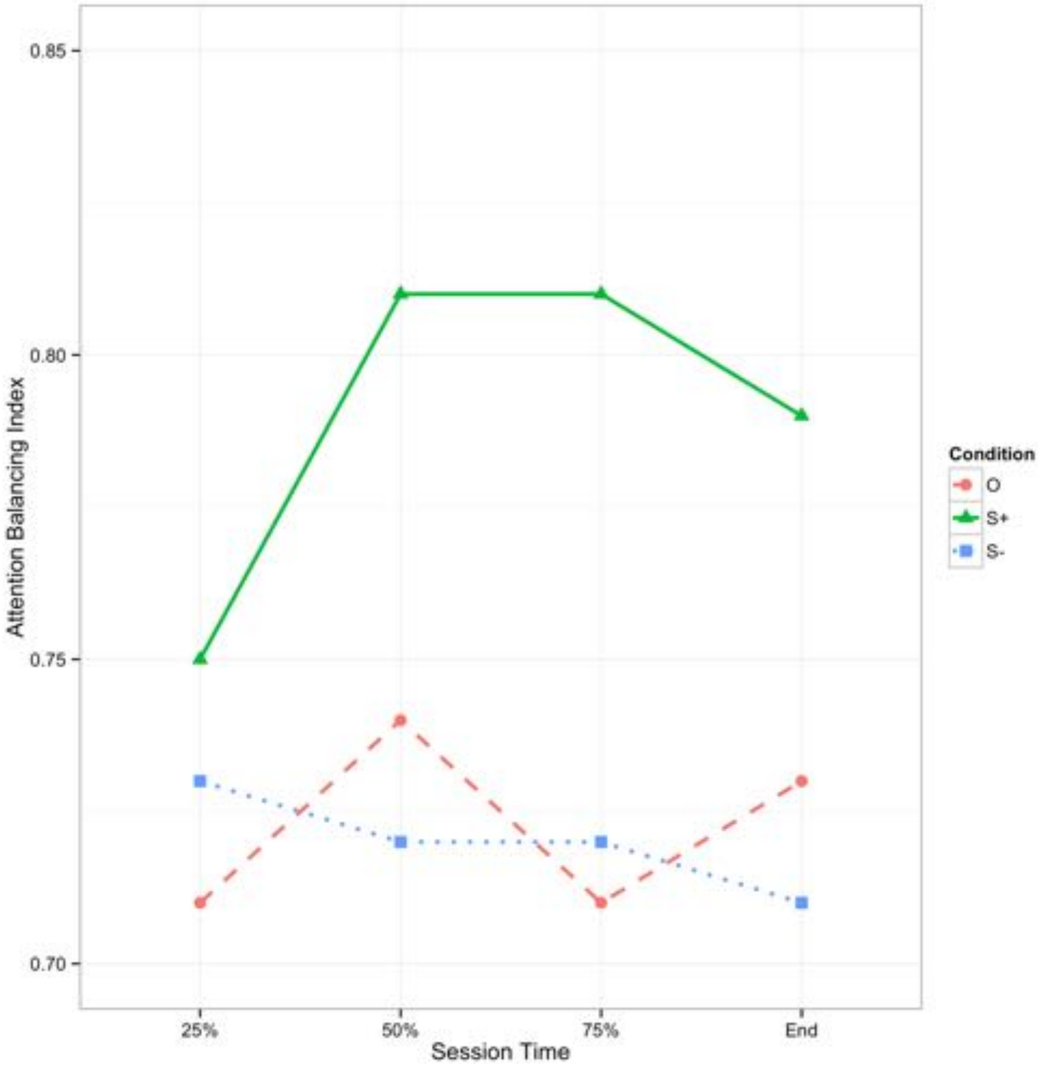

Figure 4. Study 2 Setting (A) and Diagrams of the Subtle Strategy: Neutral state (B) and Directive state (C)

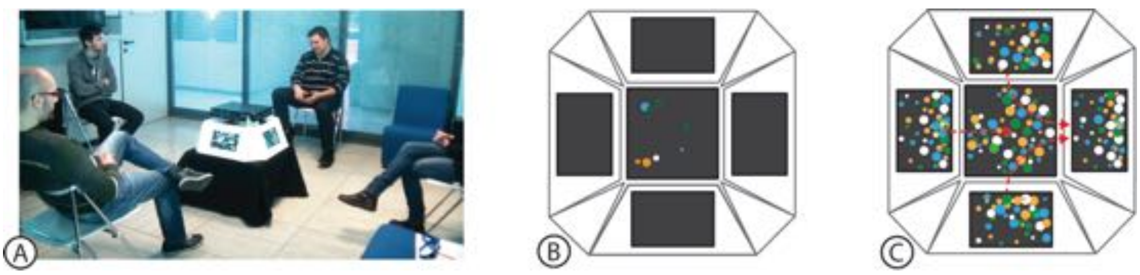

Figure 5. Average values of the Balanced Attention Index by conditions at different session times.

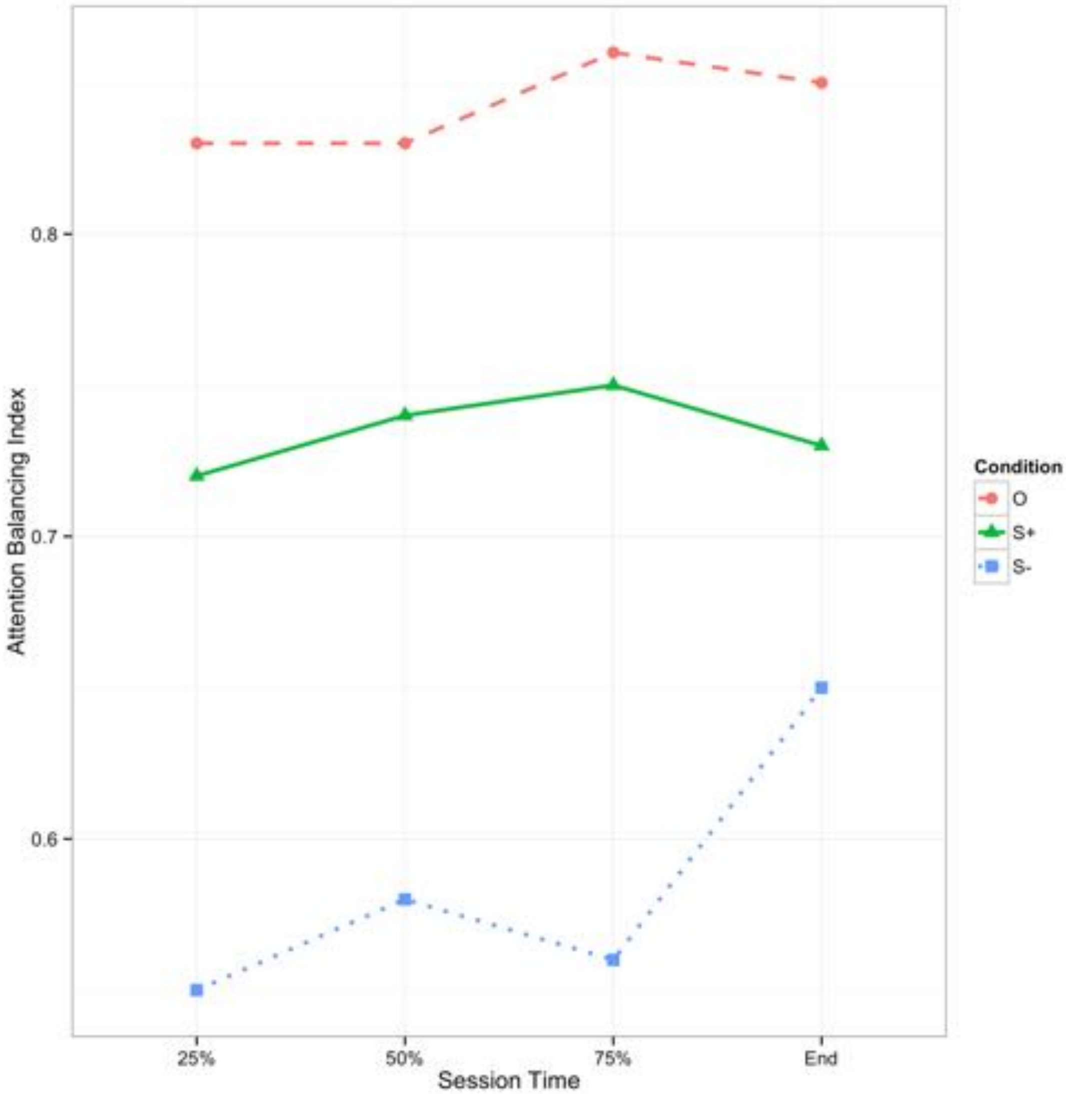

Figure 6. The figure shows percentage of gaze time directed towards the target, in the 20 seconds before the strategy was enacted and after 10, 15 and 20 seconds. Error bars show standard errors.

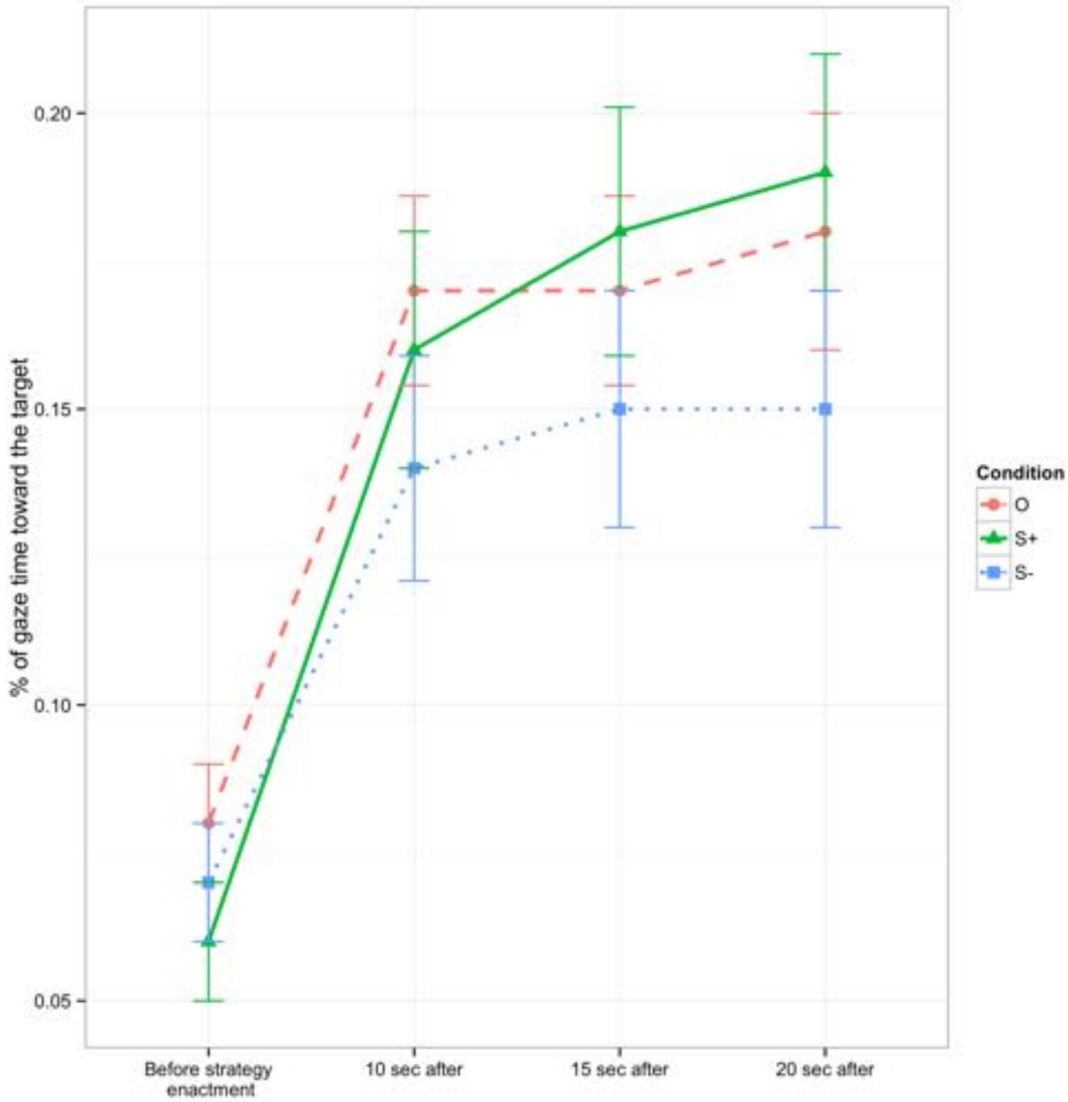

Figure 7. *Strategy activations categorized by local and global efficacy. A positive difference indicates a higher post-intervention score than a pre-intervention score. The graph shows local and global efficacy scores for each strategy activation. The upper right quadrant of the graph includes activations with positive differences.*

		Pre-post Local Efficacy	
		Negative difference	Positive difference
Pre-post Global Efficacy	Positive difference	51 (15.3%)	183 (55.0%)
	Negative difference	22 (6.6%)	77 (23.1%)

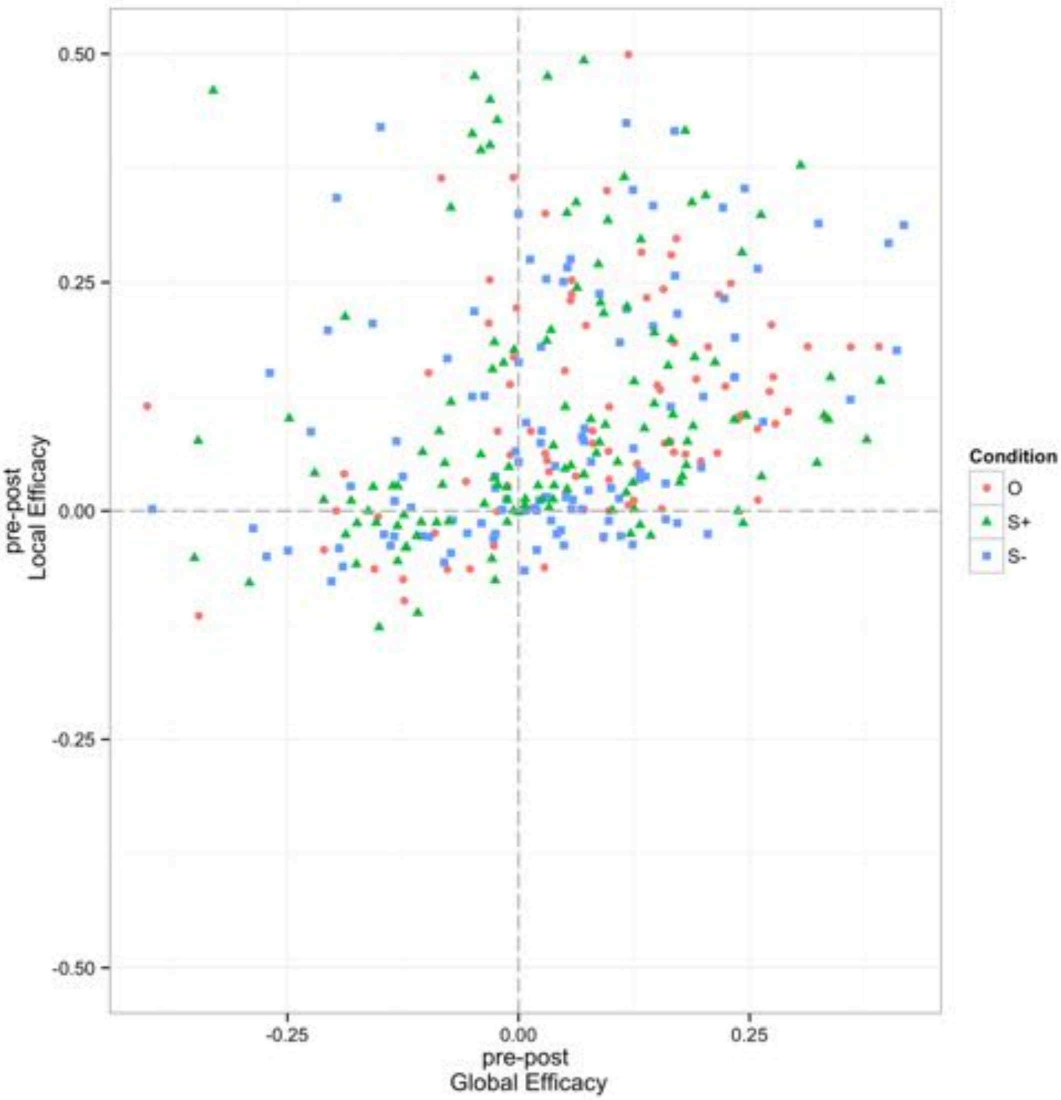

Table 1. Experimental conditions in the two studies

	Type of Intervention: Subtle	Type of Intervention: Overt
With Explanation	**S+**	**O**
Without Explanation	**S-**	-

Table 2. Dependent variables and instruments used in Study 1

Dependent Variables: Type	Dependent Variables: Variable	Dependent Variables: Measure	Instruments
Objective	Attention and gaze behavior	Balance of attention	Attention metrics from Kinect sensors
Subjective	Personal experience	Perceived effect of the system	Ad-hoc questionnaire and group interview
		Perceived disturbance of the system	Ad-hoc questionnaire and group interview
		Group cohesion	Price and Muller Work Group Cohesion Index

Table 3. Responses to the questionnaire (means and standard deviations) and ANOVA results. Items are on a 5-point Likert scale from 1 (Not at all) to 5 (Very much). N=60

Dimensions	**Subtle with explanation [S+]**	**Subtle w/o explanation [S-]**	**Overt [O]**	***F* values**	***p* values**	***Effect size***
System influence and usefulness						
I found the information displayed useful	2.90 (*0.97*)	1.17 (*0.48*)	2.13 (*1.09*)	$F_{2,57}$= 23.86	***p* < .01**	*r*= 0.67
I think the system had an influence on the discussion	2.90 (*1.12*)	1.83 (*0.96*)	2.50 (*1.15*)	$F_{2,57}$= 5.60	***p* < .01**	*r*= 0.41
I think the system had a negative / positive influence	3.65 (*0.88*)	2.88 (*0.68*)	3.13 (*0.62*)	$F_{2,57}$= 6.10	**p < .01**	*r*= 0.42
System intrusiveness						
I was distracted by the displays	2.20 (*1.60*)	2.13 (*1.50*)	2.31 (*1.69*)	$F_{2,57}$= 0.13	*p* > .05	
I was distracted by the Kinect	1.60 (*0.94*)	1.50 (*0.83*)	1.69 (*1.01*)	$F_{2,45}$= 1.38	*p* > .05	
Group cohesion	4.08 (*0.57*)	4.09 (*0.67*)	4.07 (*0.57*)	$F_{2,57}$= 0.04	p > .05	

Table 4. Dependent variables and instruments used in Study 2

Dependent Variables			Instruments
Type	**Variable**	**Measure**	
Objective	Brainstorming performance	Number of ideas; originality and feasibility of each idea	Analysis of the ideas
	Attention and gaze behavior	Balance of attention, global and local efficacy	Attention metrics from Kinect sensors
Subjective	Personal experience	Perceived effect of the system	Ad-hoc questionnaire (as Study 1)
		Perceived disturbance of the system	Ad-hoc questionnaire (as Study 1)
		Group cohesion	Price and Muller Work Group Cohesion Index (as Study 1)
	System qualities	Pragmatic, Hedonic and Appealing qualities	AttrakDiff questionnaire
	Personality	Big five traits	BFI -10 personality inventory

Table 5. Mean values and standard deviations of brainstorming performance measures

	Subtle with explanation [S+]	**Subtle w/o explanation [S-]**	**Overt [O]**
Total # of ideas	26	29	36
Average # of ideas (*SD*)	6.75 (*3.5*)	7.25 (*4.78*)	9.25 (*0.95*)
Average Originality (*SD*)	1.91 (*0.35*)	2.11 (*0.28*)	1.89 (*0.39*)
Average Feasibility (*SD*)	2.11 (*0.43*)	2.09 (*0.41*)	2.18 (*0.47*)

Table 6. Responses to the questionnaire (means and standard deviations) and ANOVA results. N=48

Dimensions	**Subtle with explanation [S+]**	**Subtle w/o explanation [S-]**	**Overt [O]**	***F* values**	***p* values**	***Effect size***
System influence and usefulness						
I found the information displayed useful	2.19 (*0.91*)	1.62 (*0.81*)	2.56 (*0.81*)	$F_{2,45}$= 4.99	$p < .01$	r= 0.42
I think the system had an influence on the discussion	2.06 (*0.85*)	2.00 (*1.15*)	3.06 (*1.12*)	$F_{2,45}$= 5.13	$p < .01$	r= 0.43
I think the system had a negative / positive influence	3.50 (*0.51*)	3.13 (*0.34*)	3.25 (*0.78*)	$F_{2,45}$= 1.78	$p > .05$	
System intrusiveness						
I was distracted by the displays	1.69 (*0.87*)	1.94 (*1.12*)	2.75 (*1.12*)	$F_{2,45}$= 4.50	$p < .05$	r= 0.41
I was distracted by the Kinect	1.00 (*0*)	1.31 (*0.88*)	1.31 (*0.60*)	$F_{2,45}$= 1.38	$p > .05$	
Personal contribution						
Compared to the others, I contributed… (1= much less, 3= same amt, 5 = much more)	2.94 (*1.06*)	3.00 (*0.00*)	2.94 (*0.57*)	$F_{2,45}$= 0.43	$p > .05$	
Group cohesion	4.42 (*0.47*)	4.05 (*0.50*)	4.48 (*0.46*)	$F_{2,45}$= 3.86	$p < .05$	r= 0.38
AttrakDiff - Pragmatic qualities	3.29 (*0.80*)	2.54 (*0.95*)	3.61 (*0.89*)	$F_{2,45}$= 6.69	$p < .01$	r= 0.48
AttrakDiff - Hedonic qualities	3.81 (*0.69*)	3.83 (*0.89*)	3.35 (*0.77*)	$F_{2,45}$= 1.91	$p > .05$	
AttrakDiff - Appeal	4.33 (*0.76*)	3.59 (*0.64*)	3.68 (*0.54*)	$F_{2,45}$= 5.98	$p < .01$	r=0.46