

Enhancing Interactional Synchrony with an Ambient Display

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ABSTRACT

Nonverbal communication is an essential part of face-to-face social interaction, conveying information about emotion and interpersonal relationships. The rigorous sensing capabilities of pervasive technologies and the subtle nature of ambient technologies make them ideal to support the production of nonverbal communication in social interactions. In this paper we present a study using an ambient technology that supports nonverbal communication, and specifically nonverbal behaviours associated with rapport. We show that an ambient display can influence a participant's nonverbal behaviour, and that participants are not aware of this change in their behaviour. We discuss these findings in terms of the design and ethical issues that it raises, and define an agenda for future work.

Author Keywords

Ambient display, biofeedback monitor for social interaction, social interaction, face-to-face interaction, rapport, interactional synchrony.

ACM Classification Keywords

H5.3. Group and Organization Interfaces: Synchronous.

General Terms

Design, Experimentation

INTRODUCTION

In recent years technologies have been deployed within social situations, for example, to initiate social interaction [24, 27], support group work [18], show interactional patterns, and share ideas [10]. Further to this, technologies [29], are being used to measure interactions in order to understand the impact of social dynamics and nonverbal behaviours on processes like decision making or software development [31]. This is an important advancement for HCI since nonverbal communication is central to social interaction [2, 31], and to date, the majority of technologies that support face-to-face social interaction have tended to focus on supporting the informational, or verbal aspects of interactions.

Research suggests that being adept at encoding (sending) and decoding (receiving) nonverbal communication has a positive effect on social interaction. For example, these skills are positively correlated with social competence, high quality interpersonal relationships and smooth social interactions [15, 26]. The significance of these skills is widely recognised by the lay-person, with many books and courses available to help individuals learn to better encode and decode nonverbal communication. It is however interesting to note that nonverbal communication is thought to be performed subconsciously [23, 30, 34], and as a consequence, the intentional, or conscious encoding of nonverbal communication can lead to poorer results [23, 34]. This has led others to suggest that teaching, or training nonverbal communication skills will require extremely rigorous and multiple sessions of practice in order to be successful [30].

The intriguing subconscious elements of nonverbal communication suggest that pervasive and ambient technologies have the potential to support nonverbal communication. For example, due to the sensing capabilities of these technologies, they can be applied within authentic interactional contexts to provide continual subtle support for the encoding and decoding of nonverbal communication, in real time, and in a rigorous manner. Additionally, these technologies may be able to provide such support in a subconscious manner [33], reflecting the mode through which nonverbal communication is thought to be produced. Nevertheless, although some research is beginning to explore how pervasive technologies might *measure* nonverbal communication [31], research has yet to explore how these technologies might be used to support the encoding, or decoding of nonverbal communication in real time throughout face-to-face social interactions.

In this paper, we bring together research from social psychology with advances in HCI to explore a new role for pervasive and ambient technologies in supporting face-to-face social interaction. Focussing initially on the ambient aspects, we present an exploratory study which investigates how an ambient display that responds to specific nonverbal behaviours within face-to-face social interactions impacts on the perceptions and the mechanics of an interaction. After reviewing current approaches for pervasive technologies that support face-to-face interactions, and the role of nonverbal behaviours in communication, we

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CHI 2011, May 7–12, 2011, Vancouver, BC, Canada.

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describe a study, undertaken to evaluate the impact of an ambient display on participants' self reports and observers' perceptions of a social interaction, as well as to better understand the issues of designing and deploying such technologies. In the final section of this paper we discuss the results of this study along with the design and ethical implications of this work.

The main contribution of this work is to identify the potential value of ambient displays in supporting the subconscious elements of face-to-face social interaction and to articulate future research directions to be explored from an HCI perspective. The results of this work will be of interest to those seeking to support face-to-face communication, collaboration, and group work, as well as those seeking to improve or teach social skills.

RELATED WORK

There are a number of technologies which seek to support face-to-face interaction [9, 16, 24]. One application area helps strangers make contact with one another, with a substantial portion focussed on conferences and networking experiences. Three examples are Ticket2Talk [24], which uses RFID nametags to display information about a conference attendee's interests whenever they stand near a display, iBand [16], a wearable technology that exchanges personal information, similar to that found on a business card, through a handshake, and GroupWear [9], also nametags that share ideas and exchange information.

All of these systems attempt to ease the burden and embarrassment experienced in beginning conversations with a stranger, serving as a catalyst to "break the ice" in initial meetings [16]. They are designed to help people network, and find people with similar interests. Studies indicate that some participants appreciate help in putting a face to someone's name, or initiating conversation [24]. Some of these prototypes are also moving to commercial products (<http://www.ntag.com>). However, these systems demand somewhat extrovert behaviour, as noted in [25] where some attendees reported feeling uncomfortable with the "loud announcement" of their presence in an area, and where participants still needed to feel comfortable talking to a stranger about one of their interests.

The informational element is only one aspect of human communication. Both paralinguistic (i.e. intonation, speed, tempo and voice quality) and nonverbal communication (i.e. gestures, facial expressions, posture) play a significant role in the success of an interaction [15, 17, 31, 37]. HCI research has explored how paralinguistic aspects can be sensed and augmented to support social interaction. For example, both DiMicco [12] and Ara [1] have used microphones as sensors to display data back to participants with regard to turn taking behaviours within group conversation, with the aim of supporting reflection on behaviour. DiMicco's visualisations of turn taking during a group interaction allow viewers to understand who is extroverted in a group, who is dominant, who is quiet, and

who sided with whom during a debate [12]. Meeting Mediator [18] utilises the Sociometer sensing device [29] to collect paralinguistic data about a social interaction, and provide a real-time personal peripheral display on a mobile phone depicting the amount each participant has spoken, and the overall interactivity of the meeting. The results of a deployment suggest that Meeting Mediator reduces the amount of overlapping speech, as well as shortening individuals' speaking time.

Whilst moving on from supporting the purely linguistic aspect of human communication, these systems still place the emphasis of what makes for a successful interaction on the amount and evenness of vocalisation from each individual member. The importance of nonverbal communication in social interaction is widely recognised [9, 17, 31, 37], yet, apart from research on issues such as gaze and video framing in video-conferencing e.g., [28] it remains relatively unexplored in terms of how new forms of technology might support the nonverbal aspects of face-to-face communication (see [27] for an exception).

Nonverbal communication consists of signals encoded through facial expressions, gestures, postures, spatial behaviour and non-verbal vocalisations [2]. Nonverbal communication is said to have taken place when one person influences another (whether consciously, or unconsciously) through any (and more) of the signal channels listed earlier [2, 11]. Research suggests that it communicates information about emotion, interpersonal relationships, and is an essential aspect of social competence [2, 7, 20, 22, 37].

Rapport is one element of social interaction that is strongly encoded through nonverbal communication [37], and additionally theorised as key to the development of interpersonal relationships, and the success of an interaction [5]. Rapport is believed to be crucial to develop trust, to create closeness, and be included in a group [22], as well as to help interactions feel smooth [36]. In industry, managers and sales people are often taught specific nonverbal techniques to promote rapport with colleagues and clients [19]. Tickle-Degnen et al [37] conceive of rapport as being the experience of three components: mutual attentiveness, positivity, and coordination, each of which is encoded and decoded through nonverbal communication. For example, coordination (sometimes termed "interactional synchrony") has been defined as a combination of postural synchrony and movement synchrony [7].

Bernieri et al. have conducted a number of studies to explore how rapport is encoded in nonverbal signals, along with how observers understand rapport in others [for example 5, 7]. Their results suggest, dependent of course on the context surrounding the interaction, that feelings of rapport are strongly correlated with interactional synchrony (or, coordination) and interactant proximity. However, Bernieri et al's research also suggests that there is a disconnect between how rapport is encoded, and how observers decode rapport from nonverbal signals, with

observers judging the amount of rapport present in a social interaction based on the expressivity of individuals, i.e. the amount an individual talks, smiles, and uses expressive facial expressions and gestures. They conclude that this expressivity of individuals drives social judgments, even though rapport is actually encoded through much richer and diverse nonverbal signals.

Bernieri et al's work identifies an area within social interaction where some key nonverbal channels are often not attended to when making important social judgements. Our research explores the extent to which an ambient display can be utilised to amplify (or make more salient) the wide range of rich, and sometimes overlooked, nonverbal signals through which rapport is encoded. In this sense rapport acts as a test bed within which we can explore the potential for technologies to support nonverbal communication in face-to-face interactions. The study described here explores the following research questions: 1) Can nonverbal signals associated with rapport be amplified with an ambient technology to make them more salient and available for social judgement? 2) Is it possible to influence feelings of rapport by amplifying the nonverbal signals associated with rapport? 3) Can such amplification impact on the nonverbal communication within an interaction? 4) How is a such a technology perceived by potential users?

THE AMBIENT DISPLAY

There are few available guidelines to inform the design of ambient displays that amplify nonverbal signals. We therefore based the design of our display (see Figure 1) on a set of self-generated criteria: the display should not be distracting; the display should appear neutral; the display should show potential to make available the patterning of cues for subconscious processing; the display should not jar with the study environment. Given these criteria, water seemed a promising design metaphor. The visual for the display was adapted from 'Water' by Rui Gil¹. The passive version of the display is a dark blue textured visual akin to waves. The ambient version of the display is subtly animated, giving the appearance of small ripples on the surface, in response to the sensing of the nonverbal manifestations of rapport (see Figure 1). For this study, the sensing of the nonverbal correlates of rapport was carried out by Wizard of Oz (WoZ). By utilising WoZ, we replicate an envisaged future scenario where participants in a social interaction might wear pervasive devices, e.g., as part of clothing, or something akin to Sociometer [29], or alternatively, interact in a room embedded with sensors or image recognition systems that capture the gestures, postural changes, eye gaze, and back-channel responses

(e.g. "uh ha", head nods, etc.) that correlate with feelings of rapport [7] to control an ambient display.



Figure 1. A Section of the Ambient Display which Surrounds a Map Used to Aid a Holiday-Planning Task. Small Ripples Appear in Response to Nonverbal Correlates of Rapport. (See Top Left Corner for an Enlarged Ripple).

STUDY DESIGN

The primary aim of this study was to investigate whether an ambient display, responding to the nonverbal manifestations of rapport, has the potential to impact on participants' self reports of rapport, and observers' judgements of interactional synchrony. To explore this question we adapted a study design first utilised by Bernieri et al [7] which explored the relationship between self reports of rapport, observer reports of rapport, and the body language of participants in a holiday planning activity.

Holiday Planning Interaction

16 adults (8 women and 8 men) took part in the initial holiday planning part of this study. Participants were recruited via general university mailing lists. Each participant was compensated £10 for their time. The 16 adults were organised into 8 unacquainted pairs of same-sex participants (this differs from [7] where mixed-sex pairs were used). Using a repeated measures study design, each pair completed a holiday planning task twice. To support the holiday planning task, each pair worked with a wall-projected display of a world map (this differs from [7] where a physical map of the world and \$20,000.00 of play money were used). In both interactions, the map was surrounded by the ambient display (Figure 2 shows the relative size of the map and ambient display to two male participants of average height): in the experimental condition, the display responded to nonverbal communicative acts associated with rapport, while in the control condition, the display remained static. Half of the participant pairs experienced the responsive ambient display during their first holiday planning interaction, and the second half experienced it during their second holiday planning interaction. In a further variation from [7], to provide two conditions with which to assess the impact of the ambient display, the planning activity was also varied to

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<http://openprocessing.org/visuals/?visualID=66>. License: <http://creativecommons.org/licenses/by-sa/3.0/>.

maintain interest in the task. In one condition participants planned a holiday for themselves (as in [7]), while in the second condition, they planned a holiday for an older person of their choice. Again, the conditions were counterbalanced.

To avoid influencing the results of the study, the participants were told at the outset that the study was concerned with the experience of stress in planning activities and how stress impacts decision making and collaboration.

Responding to the Nonverbal Manifestations of Rapport

In the future we envisage that pervasive and wearable technologies, building on advances made by devices such as Sociometer [29], will be capable of automatically capturing participants' body language and therefore nonverbal behaviours associated with rapport. At this stage of the overall research project we wanted to decouple the questions around how rapport could be detected by technology from the question of whether ambient displays can amplify nonverbal behaviours linked to rapport, and the impact of such a display. For this reason, we adopted a WoZ approach to control the ambient display. Different individuals have different levels of interpersonal sensitivity leading to different perceptions of interpersonal body language and cues. To counter this, the same researcher manually triggered a median of six ripples to appear on the responsive ambient display whenever she observed participants manifesting nonverbal behaviours associated with rapport. Each ripple dissipated over nine seconds, growing from a diameter of 25mm to 100mm. The placement of each ripple on the ambient display was determined at random by a computer program. The schedule for detecting rapport was adapted from Bernieri et al [6]. Back channel responses and eye contact were also included in the response schedule to take into account work which suggests these behaviours, depending upon the context, are also associated with feelings of rapport [7, 17]. Hence ripples were triggered in response to:

- simultaneous movement (e.g. when the participants show change in movement that start, stop, change speed, or change directions at the same instant).
- tempo similarity (e.g. when the participants share the same rhythm in their gestures and movements).
- coordination (e.g. when the participants' behaviours mesh or combine evenly and smoothly).
- posture matching (e.g. when the participants share the same postures.) (See Figure 2 for an example).
- back channel responses (e.g. head nods, utterances showing agreement / listening such as "uh ha").
- eye contact (e.g. when participants engaged direct eye gaze).

Holiday Planning Procedure and Data Collection

At the start of the session each pair was asked to spend several minutes introducing themselves to the other participant. The participants were then asked to complete a first holiday planning task together whilst being video recorded, as described in the previous section. At the end of this task the participants individually completed a questionnaire which collected self reports of rapport (the rapport criterion measure). The rapport criterion measure (labelled post-task questionnaire during the study) contains 29 items, initially derived by Bernieri et al [7] from Tickle-Degnen and Rosenthal's theoretical and empirical exploration of rapport [37]. The rapport criterion measure asked participants to "rate yourself in the previous interaction on the following characteristics: smooth, bored cooperative, satisfied, comfortable, awkward, engrossed, involved, friendly, active and positive." The second half of the measure asked participants to "rate the interaction between you and your partner on the following characteristics: well coordinated, boring, cooperative, harmonious, unsatisfying, uncomfortably paced, cold, awkward, engrossing, unfocussed, involving, intense, unfriendly, active, positive, dull, worthwhile, and slow." Each item was rated on a Likert scale from 1 = not at all, to 9 = very. In addition, and to support the story told to participants regarding the purpose of the study, participants were asked to complete a simple self report measure of stress. This scale was included to add weight to our initial explanation of the study, it is not relevant to the current investigation, and will not be discussed further.

After a short break, the pair completed the holiday planning task for a second time, changing conditions as described earlier. At the end of the interaction the participants completed the rapport criterion measure, and a simple self report measure of stress for a second time. Following this, a semi-structured interview was conducted with each participant, covering questions such as their satisfaction with completing the holiday planning task, and their thoughts on the responsive ambient display. The participants were then debriefed. Each interview was transcribed and a theme-based analysis was conducted.

All of the interactions were recorded on three video cameras, with two cameras positioned to capture the participants' facial expressions, and a third capturing the broader interaction from the back of the room (see Figure 2). Video recording started directly after a researcher introduced the holiday planning task to participants.



Figure 2: Depicting View of Broader Interaction. Also Showing an Instance of Posture Matching.

Observer Judgements of Nonverbal Behaviours

In addition to exploring the impact of our visualisation on self reports of rapport, we were also interested in the impact of our ambient display on observers' judgements of the nonverbal behaviours within the interaction.

Here, we utilised Bernieri et al's methodology for collecting observer judgements of interactional synchrony [6], as a means of understanding how the ambient display may have influenced one aspect of how rapport is manifested through nonverbal communication [6, 7, 37]. As detailed by, and replicating, their study [6], we extracted the second minute of each holiday planning interaction from the video data collected from the video camera at the back of the room. This video data was then treated to remove sound, as well as remove any movement from the ambient display. Finally a mosaic effect was applied to the video to focus attention on the timings and patterns of movements, rather than other salient features of social interaction, such as facial expression. These one minute video segments were then used as stimuli for judgements of interactional synchrony. According to Bernieri et al [6] this technique has the advantages of enabling a observer to focus on the overall behaviour of interactants, rather than fine-grained analysis of a few distinct behaviours. The method does not attempt to define what it means to be coordinated; it simply assumes that when behaviours are harmonised, simultaneously occurring, and similar that observers will perceive these behaviours as synchronous. Additionally, such a technique is scalable enabling studies to show statistical power.

Twelve untrained observers served as judges of interactional synchrony. These observers were recruited from within the University, but were neither participants, nor involved in the project. Observers received no compensation for their participation. Our untrained observers were asked to access a web-based form, to view and rate each anonymously named video in turn. Before the observers completed the judging task, they were introduced to the concept of interactional synchrony (amalgamated from [6]) as follows:

“We consider interactional synchrony to be a dynamic aspect of interpersonal coordination where the movements of interacting individuals become organised in time and space. Things appear coordinated, harmonised and synchronous to the degree that they constitute a perceptual unit, when they appear to fit together”.

Each observer was then asked to rate each video segment along three Likert scales described as follows: coordination (to what extent do the pairs' behaviours mesh or combine evenly and smoothly), simultaneous movement (e.g. if one person kicks their foot at the precise instant another swings their arm it is considered a simultaneous movement), and posture similarity (e.g. are they both sitting upright? Do they both have one hand on a hip?). The observers scored each measure on a scale from 1 = “no X” to 8 = “a lot of X”.

RESULTS

This section provides an analysis of the relationship between the ambient display, self reports of rapport, and observer judgements of rapport. We also provide a themed analysis of the interview data.

The Relationship between Self Reports of Rapport and the Ambient Display

All 29 items of the rapport criterion measure were highly intercorrelated. The Cronbach alpha reliability coefficient for the entire scale was 0.90.

A rapport score was calculated for each individual in each interaction as the mean score reported across all items of the rapport criterion measure. A pair rapport score in each interaction was calculated as the mean of the two rapport scores calculated for each individual belonging to the pair. There was very little difference between the mean individual rapport score for interactions where an ambient display amplified nonverbal behaviours associated with rapport ($M = 181.81$, $SD = 21.88$), and where the ambient display remained static ($M = 181.62$, $SD = 22.35$). Similarly, there was very little difference between the mean pair rapport score for an interaction when supported by a responsive ambient display ($M = 181.81$, $SD = 12.93$), and when no support was offered via the ambient display ($M = 181.62$, $SD = 15.60$). Two Wilcoxon signed-rank tests confirmed no significant differences between these pairs of scores.

The Relationship between Observers' Judgements of Nonverbal Behaviours and the Ambient Display

The level of reliability for each of the three measures of interactional synchrony (coordination, simultaneous movement, and posture similarity) was high, with the calculated Cronbach's alpha for coordination = 0.84, for simultaneous movement = 0.91, and for posture similarity = 0.77.

An observer judgement of coordination was calculated for each video as the mean value of observers' ratings of coordination associated with that video. The same

procedure was followed for simultaneous movement, and posture similarity. For each video, interactional synchrony was calculated as the mean value of the associated observer judgements of coordination, simultaneous movement, and posture similarity.

Figure 3 presents the mean of each observer judgement for the two conditions. The bar chart illustrates a general positive trend where the responsive ambient display resulted in higher observer judgements of coordination, posture similarity, simultaneous movement, and interactional synchrony. A Wilcoxon signed-rank test indicates that the participants showed significantly more interactional synchrony when their encoding of nonverbal manifestations of rapport were supported by an ambient display ($M = 4.88$, $SD = 0.88$), than when not ($M = 4.31$, $SD = 0.98$), $T = 1.00$, $p = 0.01$. In addition, the participants were significantly more coordinated when supported by an ambient responsive display ($M = 4.90$, $SD = 1.01$), than when not ($M = 4.40$, $SD = 1.14$), $T = 4.00$, $p = 0.05$. Finally, the pairs were also found to show significantly more posture similarity when supported by a responsive ambient display ($M = 5.37$, $SD = 0.56$) than when not ($M = 4.66$, $SD = 0.99$), $T = 1.50$, $p = 0.03$.

□

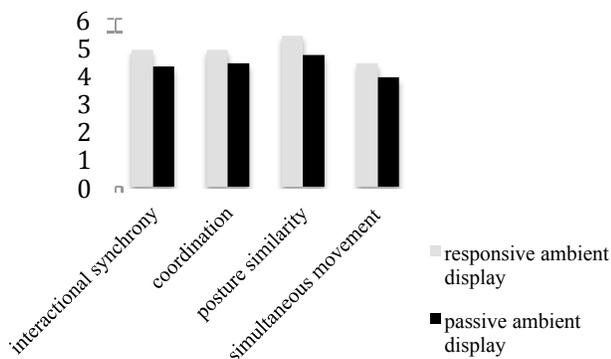


Figure 3: Mean Interactional Synchrony Ratings as a Function of the Amplification of Rapport through an Ambient Display

Participants' Thoughts on an Ambient Display that Supports Nonverbal Communication

A semi-structured interview was conducted with each participant after they completed both holiday planning tasks to understand their experience of taking part in the study, their thoughts on our representation of rapport, as well as to provide inspiration to further the design of technologies to support face-to-face interaction. The interviews were conducted in the same room as the study, with the length of interview variable, lasting between 20 and 40 minutes. A qualitative inductive analysis was applied to the data with themes identified by the authors based on both a deep reading of the data and the study's research questions. Here we provide an overview of the interview data around two main themes: representing social interaction; appropriateness of technology in face-to-face interaction.

Representing Social Interaction

At the outset of the interview all participants were asked whether they had noticed any movement on the display during either of the holiday planning tasks. Half (8) of the participants reported that they did not notice any change in the ambient display. The remaining participants reported to have noticed movements on the display whilst they had completed the task, but had thought the movements were completely unrelated to their interaction, or the task. In fact, the majority of these participants reported that they had thought the ambient display was a screen saver.

For the half who reported having noticed movement on the display, only two participants reported that the ambient display was a distraction from the social interaction, with one participant reporting that she found herself watching the ambient display whilst completing the planning task with her partner.

Participant 10: *"Yes, I thought it was a screensaver, because I... I don't know. I guess I didn't think about it, because it's got programme bars, so it's not a screensaver, but that's what I thought it was and I found myself watching it..."*

After this line of questioning the participants were debriefed, and told the real purpose of the study. The interview then moved on to focus on the future design of ambient displays for social interaction. There was agreement amongst participants that a representation of social interaction should not distract from the interaction itself. Additionally, several participants felt that the function of the technology would need to be obscured - otherwise participants worried that the ambient display may cause unnecessary anxiety. For example, two participants were concerned that an ambient display such as this might highlight less positive interactions, and instigate a negative feedback loop.

Participant 17: *"So, if you had a very disharmonious interaction, you might have the chance of instigating a negative feedback loop where you kind of start to go downhill and then the environment changes, and that makes you more angry and then..."*

Both Participant 9 and 12 felt that the function of the technology would need to be hidden in order to be effective.

Participant 9: *"That was... I felt manipulated at that point, so I think there's a point at which... if one's aware of it, then you're... you have to start changing it, I'd have thought..."*

Participant 12: *"Yes, if you knew too much about the workings of it, then it would become less effective then."*

Additionally, some participants thought that if the technology was understood by users, then it might become a stigma, indicating to others that a particular person had difficulty in social interactions.

Participant 3: “...so just bringing something like that to anything and people knowing about it immediately puts... you know, think that you’re trying to hone your skills or you’re not confident, so I don’t think that... I wouldn’t want that, I suppose.”

The Appropriateness of a Technology that Supports Nonverbal Communication

A section of the interview probed whether there was a use for technologies that support nonverbal communication within face-to-face interactions. Five participants felt that technology had no place providing this sort of support. For example Participant 7 told the interviewer:

Participant 7: “...if I think about communication technology for example, that wouldn’t have a purpose in face-to-face communication, because I don’t need any technology to make my communicating easier with someone, because he’s next to me.”

Participant 9 thought that the technology was superfluous since, as humans, we are already very well aware of social signalling.

Participant 9: “I prefer to respond to the person and have eye contact or not have eye contact. I mean, I’m either engaged or not engaged with them. I’m not so sure how much external things like that... I think it’s a bit too much for people to have to know that that’s going to be a signal that... in a way, we all know our signals.”

Some participants were enthusiastic for a technology that would support face-to-face communications, and particularly if it would be beneficial for some people who might otherwise have difficulties in social interactions.

Participant 18: “With the subtler points, like with people who are shy people and people might interpret that shyness wrongly when they are actually trying to get across these other feelings, than it could be really useful for some people.”

DISCUSSION

The data presented in the Results section indicates that our amplification of rapport through an ambient display increased the amount of interactional synchrony, and more specifically, the amount of coordination and posture similarity seen within an interaction by untrained observers. At the same time, interactants themselves were seemingly unaware of these increased behavioural manifestations of rapport, with no significant differences in their self reports of rapport between conditions. Although this study is based on a small sample size, these significant results are intriguing. Our main contribution here then is an initial exploration of the potential value ambient displays might show in supporting the subconscious non-verbal elements of face-to-face social interaction as well as to articulate avenues for further exploration.

Whilst we based our study on a social science study [7] to explore rapport, we made several changes to the method in

order to address our research questions regarding ambient displays. For example, our participants did not use physical money, or a physical map in planning their holidays. Although these changes are relatively small, they are important. Bernieri et al hypothesised that the physical elements of the task (money and map) were influential on the amount of interactional synchrony experienced by participants [6]. This renders a direct comparison between our results and Bernieri et al’s dataset difficult. As such, the discussion presented here focuses on the research questions driving this work, and the ethical questions surrounding ambient displays such as the one presented here.

Pervasive Technology Can Influence Interactional Synchrony in Interactants

As described above, interactional synchrony appears to increase, as measured by untrained observers, when an ambient display is used to amplify the nonverbal signals associated with rapport. This is an important finding when taking into account the available empirical evidence that links synchronous movement to feelings of trust, smoothness in an interaction, and relationship building [22, 37]. What is of further interest is the finding that although participants’ nonverbal communication was perceived to have changed when the ambient display responded to behavioural manifestations of rapport, participants were unaware of this change. The statistically significant change in nonverbal communication did not impact upon the participants’ self reports of rapport. In other words, although the participants manifested increased rapport in a bodily sense, this did not feed into a greater sense of rapport in a conscious, or cognitive sense.

There are a number of reasons why this could be the case. For example, it is possible that the modality chosen to represent interactional synchrony was incorrect. Half of the participants were aware of movement on the ambient display, and some reported that this movement had been distracting. From this we might infer that the display reduced eye contact as the representation drew the eyes from an interactional partner, even if only for a short period. Literature suggests that eye contact is a crucial element of social interaction, impacting upon turn taking behaviours [17]. It is also linked to two components of rapport: mutual attentiveness, and positivity [37]. So, by reducing the amount of eye contact, we may have inadvertently negatively affected judgements of positivity and mutual attention, and thereby feelings of rapport.

Further to this, Tickle-Degnen et al have theorised about the relative importance of three nonverbal components of rapport (positivity, mutual attentiveness, and coordination) throughout the lifetime of a relationship [37]. In this model, positivity is considered to be particularly important to feelings of rapport in initial encounters among strangers, whilst coordination becomes more important to the evaluation of rapport in later interactions, where there is an increased familiarity amongst participants. As such, it is

possible that although increased coordination was experienced by participants, these experiences of greater coordination did not feed into participants' models of what rapport feels like in initial interactions between unacquainted people, or in addition that this increased coordination was countered by a decrease in mutual attentiveness, and positivity. Further work collecting observer judgements of mutual attentiveness and positivity would allow us to assess this hypothesis.

Finally, the statistically significant differences in observers' perceptions of nonverbal communication were small. As such, perhaps these changes in behaviour were not sufficiently perceivable by those individuals taking part in the interaction to feed into their interpersonal judgements.

Influencing Social Interaction Subconsciously

The interview data suggests that the display was subtle enough that half the participants seemingly did not notice changes in its appearance over the course of the 10 minute interaction. Even when participants reported being aware of the movement on the display, they dismissed this movement as a screen saver which had no relation to themselves, or the interaction. Yet, the ambient display which amplified nonverbal manifestations of rapport did indeed appear to influence the overall level of interactional synchrony, and more specifically the level of coordination, and posture similarity within the interaction as judged by untrained observers. The visible availability of additional information via the ambient display, reflecting the nonverbal communication, seemingly reinforced and enhanced participants' behaviour and interactional body language without the participants being aware of this influence. This suggests that the ambient display may have contributed to the subconscious processing of nonverbal communication, as described by [23]. This finding complements [33], where ambient displays seemed to subconsciously encourage healthy lifestyle choices.

The ambient display discussed in this paper could be described as an ambient persuasive technology [14]. The ambient display, and the results of its application so far raise ethical questions, particularly when one considers the empirical link between interactional synchrony and trust [22]. In effect future iterations of such a technology may have the potential to subconsciously change people's attitudes about a given person (or product), which in turn may influence conscious decision making processes.

However, it is important to emphasise that people already make these subconscious social judgements [23, 30] and that the technology described here is only *responding* to the nonverbal manifestations of rapport as displayed by the participants. In this sense it is very much like the technologies described by Berichevsky et al [4], it is a technology that amplifies human behaviour to possibly persuasive ends, but without the human behaviour, this technology has no persuasive power. This argument is

entangled with the current workings of our technology: at present, the display and its response to synchronous movements are under the control of a "wizard". If further work with future iterations of the technology show that amplifying synchronous movement leads not only to greater coordination within an interaction, but that this coordination can be converted into a greater sense of rapport, then an individual outside of the interaction continuing to control the visual representation, and amplifications could arguably be less ethical. At present, we believe that the amplification of nonverbal social signals has to be directly coupled with those social signals occurring within the interaction to influence feelings of rapport. That said, this is an important avenue for further research, the results of which will guide the ethical application of technologies that support nonverbal communication in face-to-face interaction.

Additionally, as the technology moves out of the control of the "wizard", and into the control of sensors and what will effectively be an automated decision making technology, there will be new ethical implications. It will be important to understand the potential impact of the technology making errors when identifying and amplifying behaviours that appear to be related to rapport. For example, how would such a technology differentiate between an interactant mocking, rather than mirroring another, and what would the impact of mistaken amplifications be?

Applications for Ambient Displays in Social Interaction

Supporting the Production of Nonverbal Communication

This study points to the potential for technology to provide real time support to interactants in the production, or encoding, of nonverbal communication during face-to-face interactions. However, whilst our data analysis suggests that the ambient display may have engendered more encoding of "useful" nonverbal behaviours, the increased availability of these behaviours did not translate into feeling that the interaction was more successful. It will require further work to unpack why this is the case, but we are particularly interested in how a modality might better amplify moments of interactional synchrony, and are currently investigating whether other modalities might be better suited to amplifying such moments.

The results from this study suggest that ambient and pervasive technologies could support nonverbal communication for a range of different users and contexts. For example, some research suggests that those who feel excluded from a social group (and therefore perhaps shy people) encode more of the nonverbal communicative acts that lead to smoother interactions than the non-excluded [21]. In corroboration, there is evidence that shy people believe that the nonverbal signals they produce are often ignored in favour of the talkativeness, and the self expression of others [35]. This position is supported by research [7] which indicates that social judgements are often made based on more extroverted behaviours such as smiling, and talkativeness. As such, shy people may be

contributing to a social interaction in a nonverbal manner, but these contributions may be overlooked in favour of more explicit social signals. It also suggests that shy people may feel happy contributing to an interaction through nonverbal channels, where they may feel uncomfortable maintaining an interaction by verbal means. Future work within this area could seek to develop ambient displays, and pervasive technologies that can amplify, or draw attention to, a shy participant's contributions to a social interaction, and as a result make this nonverbal contribution to a social interaction more available to the non-shy.

Better Supporting Collaboration within Groups

There are a number of pervasive technologies currently available that support face-to-face group work [for example 12, 18]. These technologies tend to emphasise the role that turn taking, and evenness in contribution play in good collaboration. Yet, research conducted with children solving a maths problem in small groups suggests that it is not necessarily evenness in turn taking that leads to successful collaborations [3]. Instead the critical difference was the way in which a group responds to suggestions and possible solutions from individuals. In tandem with this, the researchers found successful collaborations featured greater amounts of *connected* turn taking – where the conversations of participants were well aligned to a particular topic, or problem. To aid this mutual attention, groups coordinated themselves and their work through the use of physical artefacts in the environment, conversational devices, and *coordinated* physical movements. Barron [3] therefore argues that groups must not only focus on the content space of a task, or problem, but also on the relational space. Given the positive influence our technology had on coordination, future iterations of our technology may be well placed to support this relational aspect of group work.

Challenges in Applying an Ambient Display to Support Social Interaction

There are some continuing design challenges around creating technologies that can support nonverbal aspects of face-to-face communication. For example, we found that there was a mixed desire amongst our participants for this type of support. In particular, our participants worried about the negative connotations of such a technology, for example, people being able to see the success (or not) of their interactions and conversations, and the stigma that could be attached to using such a technology. To counter this, some of the participants felt that the function of the technology would need to be obscured from users in order for it to remain effective (a need supported by [23]). These comments lend support to our choice to create an ambient display, rather than a display that used numbers or words to denote nonverbal communication within the social interaction. It also suggests a delicate balance regarding the visibility (or perceptibility) of the ambient display and its purpose. For example, how should design balance the need to provide socially anxious people with a more salient means of participating, whilst not distracting interactants

from their conversation, or producing negative judgements about an interaction, or indeed a person?

CONCLUSIONS AND FUTURE WORK

The work described here has sketched the possible opportunities for research around ambient and pervasive technologies which support nonverbal communication. Further research is needed, for example, to understand whether other modalities may be more appropriate for amplifying nonverbal communicative acts, and, whether the fine-tuning of modality can translate the enhanced encoding of nonverbal communication seen in this study to an improvement in the decoding of nonverbal communication. Considerable technical effort will also be required to design pervasive sensing technologies that are able to detect the nonverbal behaviours relevant to social interaction and respond in real time. Our investigations have shown that an ambient display has the potential to influence the nonverbal communication within pairs completing a collaborative task. In addition, the data collected suggests that the ambient display was operating on a subconscious level, scaffolding individuals' use of nonverbal communication without his or her conscious awareness. This work takes a small step towards defining a role for ambient and pervasive technologies that moves beyond supporting solely the information and verbal aspects of face-to-face interactions and collaboration, to technologies that support the interpersonal and relational aspects of social interaction.

ACKNOWLEDGEMENTS

This work has been funded by the EPSRC, grant number EP/F064330/1. Many thanks to all the participants and observers who contributed to our study and Dr. Amanda Carr who kindly guided our statistical analysis.

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