# Hey Man, you're invading my Personal Space! Privacy and Awareness in Collaborative Music

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## ABSTRACT

This research is concerned with issues of privacy, awareness and the emergence of roles in the process of digitally mediated collaborative music making. Specifically we are interested in how providing collaborators with varying degrees of privacy and awareness of one another influences the group interaction. A study is presented whereby nine groups of co-located musicians compose music together using three different interface designs. We use qualitative and quantitative data to study and characterise the musician's interaction with each other and the software. We show that when made available to them, participants make extensive use of a private working area to develop musical contributions before they are introduced to the group. We also argue that our awareness mechanisms change the perceived quality of the musical interaction, but have no impact on the way musicians interact with the software. We then reflect on implications for the design of new collaborative music making tools which exploit the potential of digital technologies, while at the same time support creative musical interaction.

## Keywords

Awareness, Privacy, Collaboration, Music, Interaction, Engagement, Group Music Making, Design, Evaluation.

## 1. INTRODUCTION

The creation, performance and enjoyment of music has always been a social activity; people make music in groups, perform in front of audiences and dance together at concerts. It is not surprising therefore that a recurrant theme within the Computer Music community has been the creation of physical interfaces and software environments for collaborative musical interaction. However despite attempts to design for electronically mediated musical collaboration, computer based music-making is often a solitary activity. This is partially because many existing commercial computer music tools are intended for single user operation [15], while research into the design of multi-user software instruments has only touched upon the *human* aspects of collaboration and interaction. We believe this deficit applies to remote interaction (e.g., via the internet) and real-time co-located musical engagement, the domain we are specifically interested in.

Fortunately, looking to other domains, such as Computer Supported Co-operative Working (CSCW), we can see that a great deal of attention has been directed towards the study of collaborative activities. Here, features such as awareness, task management, coupling and communication have been rigourously examined, often resulting in guidelines for the development of groupware which more adequately supports the requirements of computer supported collaboration.

While similar to CSCW studies, our research focuses on the open-ended and less task-based context of computer supported musical interaction. Questions we might ask include how musicians gather and use information about each other activities, how roles emerge during the creative process, and how musicians control the availability of their ideas and contributions. By studying these group processes we hope to gain insight into the design of new software to more adequately support collective musical interaction. Finally, we believe that our research could provide insights into the design of software to support other forms of collective computer supported creativity.

The rest of this paper is structured as follows. Section 2 discusses related work, including current research in musical interface design, and relevant ideas from the field of CSCW. Section 3 introduces our exploratory study, describes the multi-party music software we have developed and discusses the modes of data collection we have employed. Section 4 presents our quantitative and qualitative data analysis. In section 5 we reflect on our data and characterise the interaction which took place in our study. Section 6 points to implications for the design of new multi-user music software and outlines future research directions. The paper is concluded in section 7.

## 2. RELATED WORK

The following section introduces previous work which relates to our research, focusing primarily on the fields of computer music and computer supported collaboration.

### 2.1 Musical Computer Networks

The *League of Automated Composers* and the *Hub* [11] are frequently cited as seminal proponents of networked musical performance [26, 1]. Members of these early computer music groups wrote music generating programs which communicated via serial interfaces and bespoke messaging protocols. While long-distance real time musical collaboration had been demonstrated by the Hub in the 1980s [11], the increasing uptake of the internet made larger scale collaboration more feasible, and various remote music collaboration services such as *ResRocket* [1] [1], *Daisyphone* [3] and *Web-*

[1] http://www.jamwith.us/about_us/rocket_history.shtml Last Accessed 15 June 2008


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*Drum* [4] were developed. These web based systems typically support synchronous or asynchronous collaboration over large geographical distances, and use low-bandwidth protocols such as MIDI to minimise network latency. Weinberg [26] presents a theoretical framework for classifying types of interconnected musical networks, based on their system architecture, network topology and style of interaction. This framework considers the types of network configuration, the structure of the activities undertaken using the network, and the types of parameters made available to users, however it does not consider what information should be presented to users in order to support interaction, collaboration or engagement.

## 2.2 New Musical Interfaces

As well developments in internet based musical interaction, the last decade has witnessed a new generation of collaborative musical interfaces which represent a departure from traditional screen based interaction. By way of comparison to the musical networks discussed in 2.1, a feature of these new interfaces is an emphasis on co-located interaction involving intimacy and co-dependant connections between musicians. Examples include the *BeatBug Network* [27], *Reactable* [19] and *Tooka* [8]. Finally, mobile and pervasive experiences such as *Sensory Threads* [9] engage groups of people in musical activities on the city streets. For a more detailed overview of the field we refer the reader to Blaine and Fels [2], who present a classification of these types of musical interfaces, based on features such as the number of participants, interface type, location, and learning curve.

### 2.2.1 Summary

While the Computer Music community has directed lots of effort towards the development of new forms of musical interaction, and has developed classifications for these interfaces, less time has been spent in evaluation, or in investigating the nature of group musical interaction. We therefore turn to CSCW to inform our research.

## 2.3 Computer Supported Co-operation

Computer Supported Cooperative Working (CSCW) studies the nature of collaboration in the workplace, with the intention of designing software to better support group work.

### 2.3.1 Awareness

Awareness is a central focus of CSCW. For our purposes, *Awareness* can be viewed as a person's knowledge of their environment. This knowledge might include the location and activities of people [7], as well as a memory of previous events, and the state of systems within the environment. It has been noted that an individual's awareness information is not static, but is maintained over time, during an individual's conduct and interaction, while the process of maintaining awareness is almost always performed in support of some other activity [14, 17], meaning that individuals do not simply posses awareness information, but must gather it throughout the course of an activity.

Awareness is however difficult to measure, as it resides within the individual. A common method of evaluating awareness support in software is through a comparison of task executions, where participants are presented with different levels of awareness between experimental conditions. For instance Gutwin [13] measures factors such as task completion time, communication efficiency and perception of effort using two versions of a collaborative software application.

### 2.3.2 Awareness in Musical Interaction

Gates [10] describes the kinds of awareness information DJs gather about their audience when performing in night clubs, and proposes several technological solutions to aid DJs in collecting this information. Within the context of multi-party musical interaction awareness has been considered by Bryan-Kinns [3] in a study which investigates the relationship between various awareness mechanisms and the level of 'Mutual Engagement'. Awareness mechanisms are also a feature of the CODES project [20], an asynchronous web-based music 'prototyping' system. CODES addresses the issue of awareness by providing users with information about the modifications, past actions and motivations of other uses. The Dasiyphone [3] and CODES are both designed for remote interaction, however awareness is also central to co-located real-time musical interaction. For instance Fels [8] notes the importance of 'mutual awareness' for successful collaboration using the Tooka, while Healey et al. [15] describe the way co-located musicians use space and gesture to co-ordinate their activities.

### 2.3.3 Privacy and Collaboration

The idea of providing personal and private workspaces in group text editing has been explored by Dourish [7] and Olson [23]. More recently, researchers have investigated the provision of personalised audio feedback with Multi-Touch interfaces [21] and personal information spaces in multi-user tabletop computers [25]. Dourish [7] and Heath [17] observe that within group-work, people shift between individual activities and tightly coupled collaboration, while Heath [17] notes that individuals often design their actions to initiate collaboration and make public information which is potentially relevant to others.

Gurevich [12] investigates the issue of privacy in *JamSpace*, a music environment in which users have access to a hierarchy of workspaces, each showing an increasing level of information to fellow collaborators. Although JamSpace investigates levels of privacy within multi-party music-making, the JamSpace project does not focus specifically on the issue of inter-participant awareness, and differs from our approach as it considers levels of privacy at the level of the individual, rather than at the lower level of specific musical contributions, as explored in our research.

## 2.4 Differences between Group-Work and Group Musical Interaction

This section highlights distinctions between group music making and the activities commonly studied in CSCW.

### 2.4.1 Loosely Defined Goals

Within the context of a CSCW evaluation, participants usually have a well defined task with a clear point of conclusion (e.g., designing a newspaper layout). However, musical collaboration is often loosely structured [22], and may not have a specific goal or clearly delineated outcome [18]. Furthermore, judgements about the quality of the interaction may be less informative as musicians engaged in musical collaboration may (for example) have enjoyed the process, yet could be dissatisfied with the final result.

### 2.4.2 Group Creativity

Group musical collaboration has the potential to be spontaneous, unplanned and highly creative. This form of creativity can be related to the ideas of *Flow* [6], and *group flow* [24], where participants lose themselves in the creative activity. Conversely, the types of work and tasks usually studied in CSCW experiments are less creative, and more procedural in nature.

### 2.4.3 *Sound as Medium*

Working with sound as a medium has a number of effects on the way people collaborate. For example the generation of sound may cause verbal communication to be problematic, and individuals may have difficulty speaking while concentrating on the activities associated with playing their instruments. The apparatus used by participants (e.g., headphones) may also interfere with normal conversation.

Working with sound is also unlike working with visual materials, as sound is pervasive and can be difficult to spatially localise. This means participants may be unable to gesture or orient around a sound, or use spatial ordering strategies to manage tasks and conversation, as has been observed in group drawing activities [16]. Sound is also time based, so musical activities may involve the sequencing of contributions over time.

### 2.4.4 *Rich Social Interaction*

Healey et. al. [15] point to similarities between group musical improvisation and face-to-face dialogue, identifying a turn-taking process used by participants to introduce new musical themes. Healey et al. also describe the way musicians create and maintain an 'interaction space', which they then orient around to signify (dis)engagement with the ongoing improvisation. Coughlan [5] notes that as well as playing their instruments, musicians use many other forms of representation to convey their ideas, including vocalisation, gesture and verbal communication. Similarly, Nabavian [22] notes that musicians within a group are able to successfully collaborate while at times holding entirely different cognitive representations of the music they are co-creating.

## 3. STUDY

Our study explores how awareness information is gathered and exploited by collaborators during computer-mediated musical interaction. We are also interested in the emergence of roles, how musical contributions are introduced to the group and the ways participants use, manage and configure the shared interface.

While still at an exploratory stage, our design uses three experimental conditions, each providing participants with varying levels of privacy, which range from a fully public condition where all musical contributions are visible and audible to everyone via a Public workspace, to a condition where participants can develop contributions in complete secrecy using a Personal workspace.

Our design is intended to explore the different approaches taken by collaborators when given varying degrees of information about each others activities. For instance by introducing personal workspaces we create a situation where collaborators have potentially heterogeneous representations of the music, with each participant listening to a mixture of personal and group-level contributions. Given this situation, participants may need to work harder to maintain awareness of one another, or may develop alternative strategies for managing the collaborative process.

### 3.1 Collaborative Music Software

In order to conduct our research we developed a collaborative music-making tool which allows multiple users working on separate computer terminals to create music together (see Figure 1). The software is designed for musicians, rather than novice users. Music is made by deploying music-producing 'modules' (*music modules*) within an on-screen workspace. Modules are represented as windows which contain sliders to manipulate the musical parameters of the module. The modules provided in the software can be used to create percussive parts such as bass and snare drums, and high-hat rhythms, as well as melodies, bass lines and ambient textures. By using this 'music module' metaphor, we aim to create a shallow learning curve. The software was written using a combination of Java and SuperCollider.

The software provides participants with a text-chat tool for communication, however as we are interested in real-time co-located interaction participants can also communicate verbally.

To facilitate controlled experimentation the software can be run in three different interface configurations:

**C0: Public space only.** In C0 participants only have access to a Public Space. This means all contributions, editing and experimentation are constantly visible and audible to all participants. All participants see an identical copy of the Public Space, and changes such as the movement of modules or slider positions are immediately updated across all connected computer terminals.

**C1: Public and Personal Spaces.** In C1 participants have the Public Space, as in C0, however participants are each also provided with a Personal Space, which only they can access, see and hear. Music modules can be created in either the Public or Personal space, and can be transferred between spaces.

**C2: Public and Personal Spaces plus 'Views'.** C2 builds on C1 by allowing participants to view and audition each other's Personal spaces using a tabbed window pane. Viewing grants read-only access, it is not possible to edit modules in someone else's Personal Space. At any one time participants are able to view the Public Space and one Personal Space (their own, or someone else's).

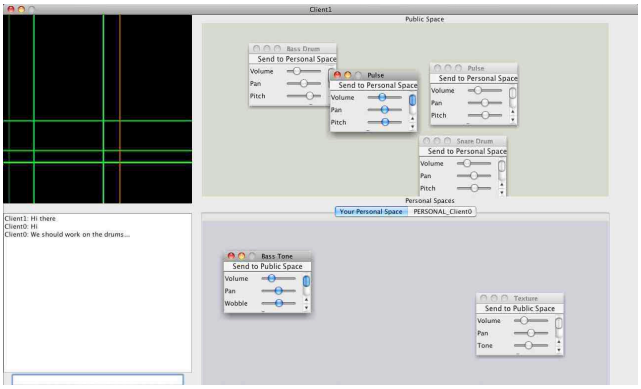


**Figure 1: Screenshot of collaborative music software. Video-window top left, chat window bottom left, Public Space top right, Personal Space bottom right. 'View' tab selector centre.**

### 3.2 Experiment Design

We chose to use groups of three participants in each experimental session, and a within-subjects design where every participant experiences all three experimental conditions. Participants sit around a table, each with their own computer terminal. Audio is delivered via headphones. Participants are all told exactly the same information at the start of the session, and given brief training with the software before starting the experimental conditions. Participant groups get fifteen minutes with each software condition. To control for learning effects the order of conditions is randomly assigned within each group.

Participants are set the group activity of creating music to compliment a short video animation loop. This task

is designed to give focus to the participants' collaboration by setting a common goal to work towards. The task is also in place to spark discussion, encourage participants to contribute ideas, and provide opportunities for consensus, disagreement and uncertainty during the course of the group collaboration. We argue that this is important because it is assumed that participants will not know each other prior to the experiment. We created three different video loops, one for each experimental condition, to give participants a fresh challenge with each interface condition. Each loop lasts around twenty seconds and is comprised of moving coloured geometric shapes. The videos are displayed in the top left corner of their graphical interface (see Figure 1) and are synchronised between participants, meaning all participants view exactly the same point in the loop at any given time. To eliminate ordering effects the videos are presented in a different order for each experimental session and are ordered independently of the interface conditions.

## 3.3 Data Collection

### *3.3.1 Questionnaire Data*

Participants filled out a pre-test questionnaire collecting demographic information. A post-test multiple choice questionnaire was administered to gather subjective opinions and impressions about the experimental conditions. Our questionnaire was based on the Mutual Engagement Questionnaire [3], which requires participants to select which experimental condition applies most strongly to a list of statements, such as 'The Best Music', 'I felt most involved with the group', 'The interface was most complex' and so on.

### *3.3.2 Interaction Logs*

Our music software logged all user interaction, including module creations, deletions and modifications, button presses, slider movements and text-chat entries. Each event log entry contains a time-stamp and an author name. We developed an automated tool to extract the following features from the interaction logs:

**Module Creations.** The creation of music modules in either the Public or Personal workspace. We are able to compare the number of creations made by each user, and between workspaces.

**Module Deletions.** Deletion of a music module.

**Editing.** Manipulation of a slider within a music module. We use a one second time delay to distinguish between the end of one edit and the start of a subsequent edit.

**Co-Editing.** Co-Editing occurs when one participant edits a music module which was initially created by another.

**Transfers.** The movement of music modules between Personal and Public spaces.

**View Activity.** The amount of time each user views their collaborators' Personal spaces.

### *3.3.3 Video and Group Discussion*

We video-taped each experiment and held group discussion at the end of each session. The discussion was structured around the prescribed themes of the *preferred interface*, *maintenance of awareness*, *the formation of roles* and *approaches to composing for the video loop*. Verbal communication was transcribed from the video recordings.

# 4. RESULTS

We recruited nine groups of three participants (27 participants in total). Participants received financial compensation for partaking in the experiment. 24 participants could play a musical instrument, with most describing themselves as of 'intermediate' (8 participants) or 'semi-professional' (9 participants) standard. 24 reported having written musical compositions on their own, while 19 reported having written musical compositions with other people. When describing their level of computer literacy only 2 participants selected 'beginner', with most positioning themselves in the 'intermediate' (12 participants) or 'expert' (13 participants) categories. 16 participants had previously used multi-user computer software.

## 4.1 Interaction Log Analysis

**Module Creations.** Using the Friedman Test we compared the number of creations in the Public Space between all conditions. Significantly more creations occur in the Public space in C0 than in C1 or C2 ($p < 0.0001$, df=2 chi-squared=25.8).

We used the Friedman Test to compare the total creations in all spaces. Significantly more creations occur *overall* in C0 (p=0.0029, df=2, chi-squared=11.69), with no statistical difference between C1 and C2.

We performed the Wilcoxon Signed-Ranks Test to compare the number of module creations which took place in the Personal and Public spaces for conditions where both were available (Conditions C1 and C2). In both cases significantly more module creations took place in a participant's Personal Space than in the Public space (for C1 p=0.0001, w=-331, z=3.97. For C2 p=0.0002, w=-307, z=-3.68).

**Editing.** Using the Friedman Test we compared the amount of editing which took place in the Public Space between all conditions. Significantly less editing overall took place in condition C0 (where participants had only a Public Space) than in conditions where participants also had a Personal Space (p=0.0344, df=2, chi-squared=6.75). We found no statistical difference in the amount of editing between conditions C1 and C2.

**Co-Editing.** Using the Friedman Test we compared the amount of co-editing which took place in the Public Space between all conditions. Significantly more co-editing took place in condition C0 (where participants only had a Public Space) than in conditions where participants also had a Personal Space (p=0.0019, df=2, chi-squared=12.57).

**Deletions.** Using the Friedman Test we compared the amount of Deletions which took place in the Public Space between all conditions. Significantly more deletions took place in condition C0 (where participants only had a Public Space) than in conditions where participants also had a Personal Space (p=0.0293, df=2, chi-squared=7.06).

**Transfers.** Transfers can only occur in conditions C1 and C2. We used the Wilcoxon Signed-Ranks Test to compare the total number of transfers between conditions. We found no statistical differences between the overall number of transfers, the number of transfers from *Personal to Public*, or the number of transfers from *Public to Personal*.

**View Changes.** In C2, participants spent on average 8.3% of their time viewing other participants' Personal Spaces.

## 4.2 Post-Test Questionnaire

Using a Chi-squared test for Post-Test Questionnaire responses we identified the following significant results (p=0.05):

- Participants felt most out of control in condition C1.
- C2 was identified as the most complex interface.
- Participants worked on their own *the least* in C0.

We also noted the following trends:

- Participants had least awareness of each other's activities in C1 (p=0.06).
- Participants enjoyed themselves least in C0 (p=0.07).

# 5. DISCUSSION

## 5.1 Interpretation of the Spaces

The Personal space was consistently interpreted as an area for experimentation and development, and participants often described their Personal Space as an area to 'prepare', 'sketch', 'test' and 'draft' contributions. Participants also described transferring or 'dropping' contributions into the Public Space once they were satisfied with the way they sounded. In contrast participants used terms such 'the main space' and 'the actual composition' to describe the Public Space, suggesting that the Public Space was interpreted as the primary focus of the collaboration. We therefore argue that a key use of the Personal Space was to produce and store new contributions, while waiting for opportune and appropriate moments within the musical interaction to integrate these contributions into the Public Space.

The quantitative interaction log analysis supports this argument, showing that Module creations happen almost exclusively in the Personal Space when it is made available to participants. Our analysis also shows more public deletions occur in C0, indicating that more contributions were rejected when participants could only work in the Public Space. This could be because participants were forced to use the Public Space for experimentation in C0, and could also suggest that the contributions which reached the Public Space in C1 and C2 were of a higher quality.

We observed significantly more co-editing in condition C0. This could be because in C1 and C2 a user can create and edit modules in their Personal Space, thus limiting the potential for co-editing. However, it may also be the case that when contributions are developed in private, users attribute more ownership to them, and as a result feel less comfortable making modifications to other people's contributions. Participants also noted in the questionnaire that they worked more as a group in condition C0, although they also felt less in control, and there is a trend for participants enjoying themselves less in C0.

In summary, it is clear that participants valued and exploited their Personal Space while collaborating, and that the inclusion of Personal workspaces affected both the perceived quality of the group interaction, and the ways the software was used during group music-making.

## 5.2 Awareness

We identified a number of qualitative distinctions between conditions C1 and C2, however we found no statistical differences from analysis of the interaction log files. During discussion, participants often expressed a preference for condition C2, as it allowed them to get an overview of each-other's work, thus helping them reduce redundancy (several people working on the same type of material). However, participants also noted problems managing the cognitive load of viewing other people's Personal Spaces in C2. The fact that no statistical differences were found implies that the awareness mechanisms changed the *quality* of the group interaction, but did not significantly affect the way the groups used the software, or their approach to the collaboration.

In almost all discussions, the issue of inconsistency and ambiguity between the workspaces is raised. Participants frequently noted being unsure which musical contributions were at group level and which were part of their Personal space. They also described difficulties in knowing which modules were currently producing sounds, and who had created them. As a feature suggestion, participants often stated it would be useful to mute the individual spaces, so as to avoid the problem of constantly hearing the sum of both spaces simultaneously. This implies participants would have preferred the software to provide more awareness information about the authorship of contributions and their location within the shared workspace.

In Condition C2 participants spent on average only 8.3% of their time viewing and listening to each others' Personal Spaces. This implies that either the feature was not especially useful or that gaining a brief glimpse of their collaborator's activities provided enough information to support co-ordination. Analysis of the text chat logs shows that participants frequently used the chat window to discuss their activities or indicate what they were doing at a given moment. This suggests that participants found it useful to exchange descriptive overviews of their activities.

## 5.3 Roles and Working Strategies

In some instances participants introduced some form of explicit management of the collaboration, for instance a 'divide and conquer' approach where participants assumed specific roles, such as working on bass-lines, or creating rhythms. During discussion, participants often noted that this approach helped them remember who was responsible for which aspects of the music. In cases where participants had access to a personal space, we observed a parallel approach, where participants would each develop ideas in private, and then in turn share their ideas with the group for scrutiny, selection and further revision. In other cases participants noted that the roles emerged spontaneously during the course of the interaction.

# 6. FUTURE WORK

Our current results indicate there is a strong difference between providing *Public Only* and *Public plus Personal* Workspaces, with participants often favouring conditions with Personal workspaces. However aside from the qualitative interpretations of the interfaces our data shows few measurable distinctions between conditions C1 and C2 (both feature Personal workspaces, however C2 also allows participants to view each-other's Personal workspaces). We therefore seek to investigate further the effects of providing additional awareness mechanisms in interfaces which feature Personal and Public workspaces. We see this investigation as divided into two concerns, those of interface design and experimental study.

The primary interface design concern is how to create new awareness mechanisms which support and enhance the collaborative process without interfering with, or introducing additional cognitive load on the musicians. To this end we are considering the effects of different audio delivery methods (speakers, headphones, spatial audio), non-aural modalities, and awareness information which is automatically 'pushed' to users, as opposed to participants being required to actively retrieve it. Experimental concerns include designing new evaluation methodologies which capture the subtle distinctions between participants behaviour given different awareness mechanisms, and devising new measures to quantify the level of engagement and quality of collaboration.

# 7. CONCLUSIONS

As a research area, collaborative computer supported musical interaction is still relatively uncharted. This study, which uses a novel group music making application, has investigated the effects of providing musicians with personal workspaces, and varying degrees of software mediated awareness. We have shown that given the choice, participants choose to develop musical contributions in their

Personal workspace, before introducing them to the group. Allowing participants to view each other's Personal spaces had no noticeable effect on the way the software was used, although participants did state they found it easier to coordinate their activities when they had some knowledge of what their collaborators were doing. However despite this advantage, some participants found it difficult to manage the additional cognitive load of remembering who was doing what during the interaction when allowed to view each other's spaces, and the additional complexity introduced by the interface was frequently highlighted in group discussions. We therefore speculate that group music applications which offer private workspaces should 'push' awareness information to participants, and could make use of graphical, textural and other non-aural channels to deliver this information. These issues and challenges are a central component of our future research.

## 8. ACKNOWLEDGMENTS

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