Personal Mobile Messaging in Context: Chat Augmentations for Expressiveness and Awareness

DANIEL BUSCHEK and MARIAM HASSIB, LMU Munich
FLORIAN ALT, LMU Munich and Munich University of Applied Sciences

Mobile text messaging is one of the most important communication channels today, but it suffers from lack of expressiveness, context and emotional awareness, compared to face-to-face communication. We address this problem by augmenting text messaging with information about users and contexts. We present and reflect on lessons learned from three field studies, in which we deployed augmentation concepts as prototype chat apps in users' daily lives. We studied (1) subtly conveying context via dynamic font personalisation (*TapScript*), (2) integrating and sharing physiological data – namely heart rate – implicitly or explicitly (*HeartChat*) and (3) automatic annotation of various context cues: music, distance, weather and activities (*ContextChat*). Based on our studies, we discuss chat augmentation with respect to privacy concerns, understandability, connectedness and inferring context in addition to methodological lessons learned. Finally, we propose a design space for chat augmentation to guide future research, and conclude with practical design implications.

CCS Concepts: • **Human-centered computing** → **Empirical studies in ubiquitous and mobile computing**;

Additional Key Words and Phrases: Mobile text messaging, chat context, mobile device sensors, heart rate

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1 INTRODUCTION

Text messaging is one of the most important casual communication methods on mobile devices today. While fast and convenient, text messages lack expressiveness and awareness compared to chatting face-to-face. Such a decrease in 'media richness' from personal to impersonal communication was described by Daft and Lengel already in the 80's [11, 35], in particular, regarding issues with equivocality of messages. Later, Walther [67] described a more differentiated view; mediated communication can also be hyperpersonal, in particular, when people utilise channels and cues for self-presentation [68]. More specifically, mobile awareness cues serve as tools for expression but also coordination and companionship [41].

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Authors' addresses: D. Buschek, M. Hassib, and F. Alt, LMU Munich, Frauenlobstrasse 7a, 80337 Munich, Germany; emails: {daniel.buschek, mariam.hassib, florian.alt}@ifi.lmu.de.

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The situation of a mobile chat partner might not be understood by others without explicitly describing it in the text messages, yet technology can also enable and facilitate *social inference* through awareness cues [39]. Looking at popular messaging apps, some additional information beyond text is currently communicated via simple status indicators (e.g., online) and a very limited set of automatic message annotations (e.g., received/read checkmarks; 'sent from phone'). Beyond that, an ever growing number of emojis aim to cater to people's expressive needs and desire for more emotional awareness. Chat partners may also utilise markup (e.g., colour, CAPS, *italic*) or visual 'memes' to enrich mobile textual conversations beyond the text itself.

We argue that most such chat features remain incomplete solutions for what we see as a fundamental lack of expressiveness and awareness. Together with the cited literature, this motivates our research: we believe that comprehensively investigating the design space of text message augmentations will further support users' expressiveness and awareness via context, that is, information and cues beyond the text.

This research is also timely with regard to available technological foundations: modern mobile devices offer a variety of built-in sensors that may be used to assess context. More and more people also start to wear additional devices and sensors. This opens up rich opportunities for augmenting mobile text messaging with context.

We explored several such opportunities in our prior work [8, 21]. Our contribution in this article is three-fold as follows: (1) We reflect on our insights and methodology based on three field studies with prototype chat apps (two published, one reported first here). Our apps implement different augmentation concepts for several kinds of context. (2) We chart a comprehensive design space for augmented text messaging. (3) We discuss lessons learned and design implications to facilitate future exploration of such augmentations.

2 RELATED WORK

2.1 Context

The term *context-aware computing* was first introduced by Schilit et al. in 1994 [52]. Since then, there have been continuous attempts by researchers to define the term *'context"* and introduce context meta models. As outlined by Zimmermann et al. [73], most definitions of context can be categorised into definitions by synonyms and definitions by examples. These synonyms include application's environment or situation. Other researchers define context by example and list elements like location, time, temperature, in addition to beliefs and intentions.

Brown et al. [7] defines context as *'[the user's] location, who they are with, what the time of day it is'*, as well as the season of the year, and the temperature. Schilit describes context sensitive systems as the ones which are aware of and adapt to the location of use, the collection of nearby people and objects, the accessible devices and changes to those objects over time [53]. Ryan et al. [51] consider context as location, time, temperature or user identity. Context is also partly described as the computing environment [51, 53], or the environment that the user's computer knows about [6]. Phone context in particular was used, for example, to allow users to define personal context-rules (e.g., switch to 'meeting mode' if phone lies still, face down) [30].

Pascoe [44] describes context in a more generic definition as a 'subset of physical and conceptual states of interest to a particular entity', which makes context subjectively defined by the receivers. Dey and Abowd [12] define context as any information that can be used to characterise the situation of an entity, that is, another person, a place or an object that is relevant for interaction. They also define context generically as primary and secondary attributed [1]. Primary contexts are location, identity, activity and time. All others are secondary, for example, address, friend lists and relationships. Perera et al. [45] offer a similar interpretation with primary and secondary contexts. Schmidt et al. [54, 55] offer two meta-models of context. In one model considering a 3D context model with *self, device* and *activity* as higher level dimensions [54]. In the second model considering human factors and physical environment as upper level context definitions with sub-contexts beneath [55]. They discuss the usage of both meta-models in mobile and ubiquitous scenarios.

Bauer et al. [3] provide a comparative overview of 13 different meta-models of context. The outcome showed that there are six overarching context categories that can be identified from most of the meta-models in the literature: physical world, individual, social groups, activity, technology and change over time. Our three presented projects of contextual chat augmentation are encompassed by multiple definitions of context. The closest is Sigg et al.'s definition [57], which includes five higher levels of context: *identity, location, time, activity, constitution and environment.* In our projects, we cover elements of context, such as user identity, physiological state and mood, physical environmental state, relative location and activities.

2.2 Supporting Awareness

The context information mentioned above may be shared as part of *awareness systems* for supporting (distributed) work groups (e.g., as a group status display [14]). Ellis et al. [17] proposed two taxonomies for such 'groupware': the first one is a time/space matrix (co-located vs. remote, synchronous vs. asynchronous). The second taxonomy lists a range of application levels (e.g., messaging, multi-user editors, group decision support).

Common to most such systems is a dual tradeoff, identified by Hudson and Smith [25], between sharing information for greater awareness and increasing risks related to both privacy and disturbance. They concluded to carefully consider the nature and amount of shared information with respect to this tradeoff. While the risk of disturbance seems higher on the receiver's end, other work also considered disturbance related to providing awareness data [61].

In the taxonomies of Ellis et al. [17], our work mainly addresses remote messaging, both synchronous and asynchronous. In their proposed perspectives, we focus on communication. We also encountered the dual tradeoff [25] in our prototype designs and user studies. Several dimensions of the design space presented here are thus informed by – and can be related to – this prior work: for example, an implicit trigger for sharing context in mobile messages reduces disturbance for the sender (e.g., less typing), yet may introduce privacy risks, compared to explicit sharing controls. Moreover, continuous context sharing fits synchronous chatting better than sporadically shared contexts; yet in users' daily lives, both temporal relationships may occur (and change rapidly) for the same chat partners.

These examples already hint at differences to other awareness work: focussing on text messaging on mobile devices, there may be no fixed group, location or timing; chat partners move through the time/space matrix as they move through their day. Privacy concerns and perceived disturbances vary, for example, depending on the chat partner and their own context. Hence, as our studies highlight, perception and usefulness of context augmentations for mobile messaging themselves depend on users' varying contexts, and relative context constellations. Mobile text messaging also sets specific constraints, such as screen space and integration into chat UIs. In summary, in contrast to earlier awareness work, our design space and reflections cater to the more dynamic predominant communication channels we use today. While the core issues of awareness systems remain the same, we focus on the particular challenges of designing for mobile devices and users.

2.3 Contextual and Affective Instant Messaging

Recently, researchers investigated different ways to sense contextual and emotional information, and to share and embed it in instant messaging applications. In this section, we present prior literature on sensing context and visualising it in the chat environment.

2.3.1 Sensing Context and Affect in Chat. Recently, researchers utilised wearables with physiological sensors for sharing bio-signals to increase affect and context awareness in messaging. Lee et al. developed *EmpaTalk* [34], a video chat application which mutually shows heart rate and skin wetness collected through blood volume pulse and galvanic skin response (GSR) sensors. *Conductive Chat* [13] uses GSR sensors to communicate arousal in chat by animating the text. Kuber and Wright used electroencephalography (EEG) and facial expressions to detect emotional cues in chat environments [31].

Another way to sense context and emotions in chats is using text analysis. Pong et al. [47], Tsetserukou et al. [64] and Yeo [72] used text analysis to infer the mood in instant messaging applications. Kaliouby and Robinson [16], Fabri et al. [18] and Angesleva et al. [2] used facial recognition to communicate in-chat emotional states via images and avatars.

For sensing and detecting contexts such as location, activity and temperature, researchers used a variety of environmental, on-body and smartphone sensor combinations. Ranganathan et al. envision a context-sensitive chat application, *ConChat* [48], which integrates information from sensors embedded into the environment, such as temperature, number of people in the room and currently running applications. Hong et al. [23] aimed to realise such a vision of a context sensitive chat using a combination of four sensor types: physiological sensors, accelerometer, GPS and smartphone sensors. Based on these, information about stress, emotions, user location, movement, weather and time of day are extracted and analysed using dynamic Bayesian networks and embedded in the *ConaMSN* desktop messenger.

In our three prototypes and studies, we cover a representative set of these sensors by including physiological sensing (heart rate in *HeartChat*), GPS (in *ContextChat*), further smartphone sensors (touch and device movement in *TapScript*; movement/activity in *ContextChat*), other behaviours (music listening in *ContextChat*) and environmental sensors (weather in *ContextChat*).

2.3.2 Communicating Context and Affect in Chat. Sensed information has to be communicated to the users. Researchers have proposed a wide range of ideas that explore various related design decisions: *Chat Circles* [66] by Vigas and Donath is a desktop chat which uses abstract visuals to represent identities and activity of interlocutors in synchronous communication. *Bubba Talk* [62] creates a mapping between text styles (e.g., capitals, exclamation marks) and different visualisations that show the chat's general mood. *CrystalChat* [63] presents the history of chat conversations based on patterns of conversation and analysis of emoticons.

While the projects above all visualise chat atmosphere post-hoc, Pong et al. [47] used a real-time presentation of the chat's general atmosphere using floating coloured circles. Tsetserukou et al. created *I_FeelIMI!* [64], which extracts emotions and communicates feedback through wearable garments (e.g., for virtual hugs).

Another way of reflecting context and emotion in chat is based on typography. Handwriting is usually regarded as a highly individual [59] (e.g., signature) and context-sensitive way of expression – people write differently on a shaky train ride than at a table at home. In a digital chat context, researchers apply effects to text to make it more personal, embed contextual information, or express emotions with text animation. The latter is referred to as '*kinematic typography*' [4].

Wang et al. [70] and Lee et al. [33] designed several text effects to convey emotions in chats. Kienzle and Hinckley [29] presented an algorithm for segmenting strokes when drawing overlapping characters at the same screen location. This enabled messaging via finger-drawing on a smartphone. Users liked the personal look and the fun experience. Iwasaki et al. [27] mapped typing pressure to font-size for chats on a laptop. Text in a desktop chat was animated, for example, with 'jumps', to express predefined emotions [4].

Apart from digital manifestations of context and emotion on screen, Rovers and van Essen researched communicating emotions in instant messaging using haptic feedback [49, 50]. They designed *hapticons*, small vibrational patterns that can be used to communicate feelings [50]. Using haptic feedback as well, Shin et al. designed *Tactile Emoticons*, which used a collection of motors, pins and coils to communicate emotions in instant messaging. Finally, Isaacs et al. presented *Hubbub* [26], a messaging application that uses musical sounds called *Earcons* to communicate context and increase awareness and connectedness in instant messaging.

Inspired by this range of options, the cues employed throughout our three studies cover several presentation concepts: *TapScript* uses smartphone sensing and dynamic typography, *HeartChat* employs physiological sensing linked to (live) colours and textual representations and *ContextChat* visualises context from device sensors and APIs via textual/iconic message annotations. These choices enable us to reflect on and discuss the impact of different presentation and integration concepts (see, e.g., Sections 4.2 and 4.4). We leave haptic/acoustic presentations for future work.

2.4 Chat Market Applications and Context

The popularity of mobile chat applications has been on the rise for the past decade. At least one billion active users reportedly chat via Whatsapp and Facebook messenger[1]. Many of the most popular applications offer contextual cues and means to communicate context and emotions. This includes the ability to send photos, videos, emojis and stickers. More recently, several messenger applications (e.g., Whatsapp) have integrated options to show if a message was sent, received or read. Apps typically now also show online status of chat partners. Facebook's *timeline*, although not a conventional chat app, offers several possibilities of adding contextual information such as location and activities. *SnapChat*, an ephemeral mobile chat application, also offers possibilities of adding filters and overlays to photos that show speed, temperature, current location and time, among other contexts. All market applications allow users to send emojis to express their mood or activities.

Commercially available wearables (e.g., Apple Watch[2]) or mobile applications (Android Heart Rate) provide the possibility of sending sensed information through other instant messaging applications. For example, the Apple watch allows users to share haptic heart rate information with others owning an Apple watch. Several activity tracking applications (e.g., Endomondo[3]), allow for sharing context information about location and activities through instant messaging applications. Facebook Messenger offers integration with diverse Third Party Apps like Spotify, Tumblr or QuizChat. For example, music played via Spotify can be shared in the chat.

Our prototypes do not offer image and video sharing, yet some of our context cues can be related to market apps: we also use heart rate, location information and played music. Integrating cues as message 'annotations' in *ContextChat* can be seen as similar to simple annotations in market apps such as 'read' marks. We go beyond current market apps by exploring different options for presentation (e.g., comparison of three heart rate views in *HeartChat*), as well as novel cues and integrations (e.g., font personalisation in *TapScript*).

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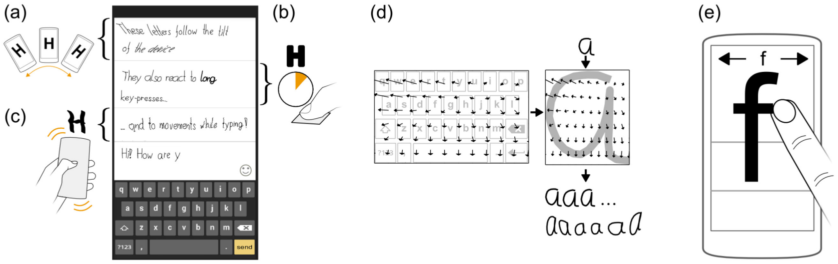
[1] https://www.statista.com/statistics/258749/most-popular-global-mobile-messenger-apps/, accessed February 2017.

[2] Apple Watch: http://www.apple.com/de/watch/, accessed February 2017.

[3] Endomondo: https://www.endomondo.com/, accessed February 2017.



These letters follow the tilt of the device

They also react to long key-presses...

...and to movements while typing!

Hi! How are y

Fig. 1. *TapScript*'s font adaptations: (a) skewing characters based on device tilt, (b) changing line thickness with key-hold time, (c) adding noisy line transformations based on device movement and (d) distorting characters based on finger placement on the keyboard. These adaptations are applied to a base font (e) that users initially set up by drawing letters with the finger.

3 EXPLORING CHAT AUGMENTATION

We explored augmentation of mobile text messaging in three projects, introduced in this section: *TapScript* [8], *HeartChat* [21], and *ContextChat*.

- *TapScript* is a dynamic font personalisation framework, implemented in a chat app. It allows users to create their own finger-drawn font. While typing, the characters of this font are rendered with further modifications (e.g., distortion), which result from the typist's current context and behaviour, assessed with device sensors (e.g., accelerometer).
- *HeartChat* is a chat app that uses a body-worn sensor connected to the mobile device to measure heart rate and integrate it into the chat. It explores three types of integration as follows: (1) automatically showing heart rate per message (snapshot at the time of sending), (2) automatically showing it per user in real time or (3) sending the current heart rate value explicitly with a button.
- *ContextChat* is a chat app that uses device sensors and web APIs to automatically augment text messages with following four types of context information: (1) music the sender is currently listening to, (2) distance between the chat partners, (3) current (device) activity (e.g., in vehicle) and (4) weather.

3.1 Concepts and Systems

This section describes the concepts and implemented prototype systems of the three projects in detail.

3.1.1 TapScript [8]. This project's core idea was to introduce font variations to personalise text messages and to augment them with subtle contextual cues. Our concept was inspired by handwriting with pen and paper, which is both highly individual behaviour (e.g., signature) as well as context-sensitive (e.g., hasty scribbling, writing on train vs. table).

To develop our font personalisation concept, we thus investigated influences on handwriting (for details see [8]). In particular, we reviewed the 21 *discriminating elements of handwriting* described by Huber and Headrick [24]. These elements belong to two groups – *style* and *execution*. The former can capture user-specific behaviour (e.g., personal style of certain characters), the latter mostly matches context influences (e.g., line precision).

We focussed on half of these elements, excluding those that do not relate to a single character, to develop five font adaptations (Figure 1) as follows: (1) a finger-drawn base font captures elements such as *class of allographs* (e.g., block vs. cursive); (2) a user-specific touch model captures finger placement and precision on the keyboard in analogy to handwriting elements like *pen control* (e.g., to distort letters when typing behaviour is less precise); (3) the device's inertial sensors capture movement to influence *line quality* (e.g., creating shaky lines when typing while moving); (4) inertial sensors also capture device orientation in analogy to a pen's *slant/slope* (e.g., tilting letters when typing on a tilted device); and (5) the touchscreen yields finger pressure and touch hold duration with which we can influence the line's thickness in analogy to a pen's *point load* (i.e., vertical force at tip).

We implemented *TapScript* in a prototype chat app for Android. Figure 1 shows a screenshot. Our app allows users to create a font by drawing with the finger on the screen, one character at a time (Figure 1(e)). Users can change and redraw this base font as much as they like at any time. Apart from this font setup, they can join a group and enter a name, that is displayed with their messages. The app offers a basic chat view in which users can send messages to users in the same group. Messages are displayed in the chat partners' custom adapted fonts. Users can also insert small finger drawings into the text via a 'smiley drawing' button.

3.1.2 HeartChat [21]. In this project, we investigated how mobile chat applications can be augmented by communicating physiological data. We argue that wearable physiological sensors can offer an additional channel to communicate context in messaging. We chose heart rate as physiological signal that is understandable and easy to be measured using unobtrusive sensors that are now embedded into many wearable devices on the market (e.g., Apple Watch, Moto 360, Fitbit). Heart rate has previously proven to be a signal that promotes connectedness in social situations [10, 36, 58].

The development of our concept is based on two steps. First, we conducted a review of related literature and commercial mobile chat applications augmented with physiological or affective information. Second, we conducted a focus group to identify core dimensions for the implementation of *HeartChat*.

Through the literature review of 22 papers and 30 market applications, and a focus group with 6 participants we set on the development of *HeartChat* through an iterative design process. It consisted of a mobile chat app for Android that integrates heart-rate information collected via Bluetooth Low Energy from commercial heart rate sensors. Its architecture utilizes the Google Cloud Messaging service[4] and a MySQL database. The database stores messages' timestamps, the text (encrypted), the heart rate and the current mode of heart rate display. *HeartChat* had three modes of display which were the outcome from our design process, namely: HeartBubbles, HeartLight and HeartButton. Figure 2 shows a screenshot of each of the three modes.

- *HeartBubbles:* Presents the heart rate upon sending a message encoded in the colour of the message's bubble, on a scale from green to red. Older message stay coloured This concept thus realises the dimensions of *persistence, history* and *implicit sending*.
- *HeartLight:* Presents the heart rate of each chat user as a circle with their initial(s). The circle continuously changes colour at 1 Hz while the sensor is connected. The circle is grey for users who are not currently online with *HeartChat* open.
- *HeartButton:* Shows a button beside the text field to send a message with the user's current heart rate as a number. No other heart rate augmentation is seen in the chat. This concept realises *raw representation* and *explicit sending*.

Both *HeartLight* and *HeartBubbles* use a colour coding to depict heart rate which ranges between green, measured as an average of two minutes of resting, and red, depicting maximum

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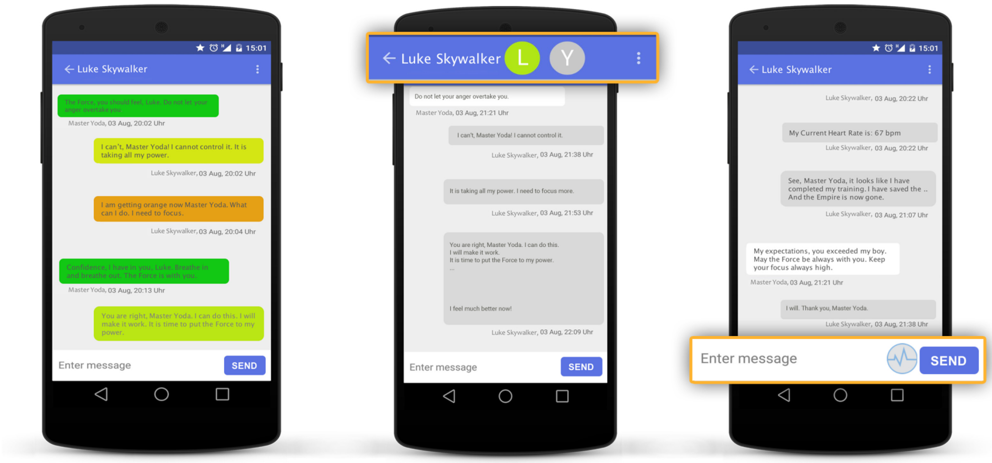
[4] https://developers.google.com/cloud-messaging/.



The Force, you should feel, Luke. Do not let your anger overtake you.
Master Yoda, 03 Aug, 20:02 Uhr

I can't, Master Yoda! I cannot control it. It is taking all my power.
Luke Skywalker, 03 Aug, 20:02 Uhr

I am getting orange now Master Yoda. What can I do. I need to focus.
Luke Skywalker, 03 Aug, 20:04 Uhr

Confidence, I have in you, Luke. Breathe in and breathe out. The Force is with you.
Master Yoda, 03 Aug, 20:13 Uhr

You are right, Master Yoda. I can do this. I will make it work. It is time to put the Force to my power.

Do not let your anger overtake you.
Master Yoda, 03 Aug, 21:21 Uhr

I can't, Master Yoda! I cannot control it.
Luke Skywalker, 03 Aug, 21:38 Uhr

It is taking all my power. I need to focus more.
Luke Skywalker, 03 Aug, 21:53 Uhr

You are right, Master Yoda. I can do this.
I will make it work.
It is time to put the Force to my power.
...
I feel much better now!
Luke Skywalker, 03 Aug, 22:09 Uhr

Luke Skywalker, 03 Aug, 20:22 Uhr

My Current Heart Rate is: 67 bpm
Luke Skywalker, 03 Aug, 20:22 Uhr

See, Master Yoda, it looks like I have completed my training. I have saved the ..
And the Empire is now gone.
Luke Skywalker, 03 Aug, 21:07 Uhr

My expectations, you exceeded my boy. May the Force be always with you. Keep your focus always high.
Master Yoda, 03 Aug, 21:21 Uhr

I will. Thank you, Master Yoda.
Luke Skywalker, 03 Aug, 21:38 Uhr

Fig. 2. *HeartChat*'s three views: (a) HeartBubbles automatically show heart rate per message, (b) HeartLight automatically shows heart rate per user in real time, and (c) HeartButton allows users to explicitly send their current heart rate value.

heart rate calculated as a function of the age as 208 − (0.7 × *Age*) [60]. The stored text of the message exchanged between interlocutors is encrypted using BlowFish encryption with a local mutual password agreed upon and set in the app.

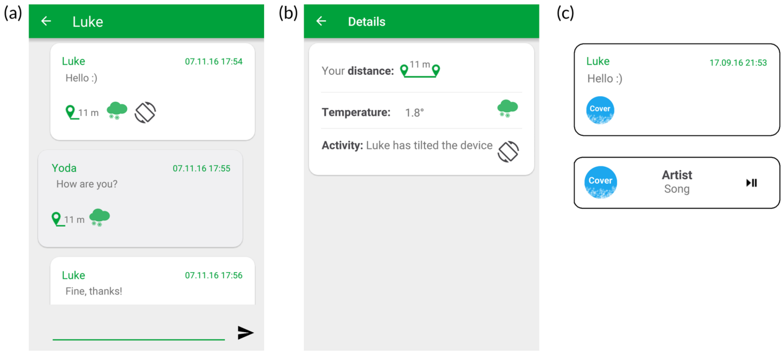
3.1.3 ContextChat. This project explored the idea of annotating text messages in mobile chats with additional context hints, which are automatically generated from device sensors (and web APIs). In particular, our hints go beyond simple automatic annotations that already exist today (e.g., 'sent from my phone').

We identified interesting context hints with a two-step approach similar to the concept development of *HeartChat*: We first conducted a literature review, as well as a review of current popular messaging apps. We then conducted a focus group to generate new ideas and to identify core context dimensions by clustering the results. We will return to these dimensions in the design space section of this article.

For our prototype, we selected four types of context as follows: (1) *music* the sender is currently listening to, (2) *distance* between the chat partners, (3) current (device) *activity* and (4) the current *weather* at the sender's location. We selected these context hints based on both expected user interest, as informed by the participants of the focus group, as well as a set of (feasibility) criteria for our field study deployment – (1) participants do not need special hardware beyond their phones; (2) correct implementation is feasible and can run on a wide range of phones; (3) context data does not vary simply due to different (Android) device models; (4) context data can be expected to change throughout typical situations in our participants' daily lives; (5) the selected contexts cover a range of our identified context types.

We implemented a simple chat application for Android, called *ContextChat*. The four selected context hints were integrated as *context widgets* – small icons that appear automatically at the bottom of a message in the chat window, if the corresponding context is available when sending the message. Touching these icons opens a detail view that displays more information, including a textual description. Figure 3 shows the chat view, the context widgets and the detail view.

We report relevant details of our implementation: played music is captured from several popular music player apps by listening to Android's media broadcasts. The music context widget displays



Luke

Luke 07.11.16 17:54
Hello :)
11 m

Yoda 07.11.16 17:55
How are you?
11 m

Luke 07.11.16 17:56
Fine, thanks!

Details

Your distance: 11 m

Temperature: 1.8°

Activity: Luke has tilted the device

Luke 17.09.16 21:53
Hello :)

Artist
Song

Fig. 3. *ContextChat*'s main views: (a) the chat view, here showing messages with the context widgets for distance, weather and activity; (b) the corresponding context detail view for the first message and (c) an example messsage and detail view showcasing the music context.

Table 1. Overview of the Field Studies Conducted in Our Three Projects

Project	***N* (groups)**	**Participants**	**Duration**	**Before use**	**During use**	**After use**
TapScript	11 (5)	5 female; mean age 25; groups of 2–3 friends	1 week	online briefing, *AttrakDiff* questionnaire	logging (messages), in-app feedback	group interview, *AttrakDiff* questionnaire
HeartChat	14 (7)	9 female; mean age 28; pairs (friends, couples)	2 weeks	briefing, *ABCCT (1)*	logging (messages, heart rate), *Heart Rate Visualisation View (1)* questionnaire	*ABCCT (2)*, *Heart Rate Visualisation View (2)* questionnaire, group interview
ContextChat	27 (11)	13 female; mean age 26; groups of 2–4 friends	2 weeks	questionnaire (demographics, device info, usage of usual messaging apps)	logging (messages, use of chat/detail views, occurrence of each type of context)	questionnaire (app in general, *Context Widgets Feedback*), group interview

The *highlighted* questionnaires are explained in more detail in the text.

the album cover, retrieved via the Spotify API. The detail view offers a play button so that the chat messages' receivers can also play the song (requires a Spotify account). Weather information is obtained from the OpenWeatherMap API. Distance is computed based on the chat partners' GPS locations. Finally, (device) activity is inferred with Google's Activity Recognition API, which offers the following activities: in vehicle, on bicycle, on foot, running, walking, still and tilting (the device, which might indicate activities such as lying down). We only consider activity events for which the API reports a confidence of more than 50%.

3.2 Evaluation

Table 1 presents an overview of our three field studies. They share a common approach: we recruited groups of people who knew each other and who were used to messaging each other on their phones. We asked them to use our prototype apps instead of their usual chat apps for the duration of the field study. Afterwards, we conducted group interviews to gather qualitative feedback. Additionally, the studies used several questionnaires. There is no IRB at our institution for this kind of studies. However, we made sure that the studies strictly complied with our institution's regulations for user studies, including a written consent form.

In the *HeartChat* study, we asked participants to use a particular mode (different between groups) for the first week. During the second week, they were free to try out all modes and to use the mode of their choice.

In *TapScript*'s evaluation, we conducted an online survey in addition to the field study. Here, we showed screenshots of *TapScript* messages. Comparing pairs of messages, survey participants were asked to distinguish individuals as well as walking/sitting. For further details, we refer to the paper [8].

3.2.1 Questionnaires. In our three field studies we employed different questionnaires together with interviews and usage log analyses. We next explain these questionnaires, omitting standard questions like demographics.

AttrakDiff. For *TapScript*, participants filled in the *AttrakDiff* questionnaire [20], which measures perceived pragmatic and hedonic quality. They answered it two times (1) before the field study – here they rated their currently used (main) mobile messaging app and (2) after the field study, now they rated our prototype chat app.

ABCCT. For *HeartChat*, we employed the *Affective Benefits and Costs of Communication Technology (ABCCT)* questionnaire [71]. This questionnaire was designed to evaluate the difference between communication technologies with respect to the following four benefits: Emotion Expression, Engagement and Playfulness, Presence in Absence, and Opportunity for Social Support. It also assesses following three costs: Unmet Expectations, Unwanted Obligations, and Threat to Privacy. We employed the questionnaire twice, once in the beginning of the study to evaluate the currently used chat market application, and once at the end of the study to evaluate *HeartChat.*

Heart rate visualisation mode. Additionally, to evaluate the different modes of heart rate visualization in *HeartChat*, we asked participants to express their agreement on a 7-point Likert scale (1 = totally disagree, 7 = totally agree) about the visualization they were using during the first week, to the following statements: 'The visualization I was using this week . . . ' (1) was clear and easy to interpret, (2) was enjoyable and fun to use, (3) made me feel close and connected to my chat partner, (4) made me understand the state of my chat partner. After the study, participants answered the same questions about all three modes.

Context widgets feedback. Participants in the *ContextChat* project rated the different context widgets with a questionnaire after the study. For each context type (music, activity, distance, weather), they rated agreement with 14 items on a 5-point Likert scale. These items assessed aspects related to aesthetics, visualisation, understandability, correctness, interestingness, relevance, automatic context annotation and privacy. It covered both sender and receiver points of view. For example, for each context we asked both 'It was interesting to receive this information' and ' . . . to send this information'.

3.2.2 Group Interviews. In all three projects, we conducted group interviews with the participants of each group who had used the prototype apps together. In *HeartChat* and *ContextChat* the interviews were conducted in person or remotely using video chat with both chat partners. One researcher conducted the interview which was audio recorded. Participants were shown data logs of their usage of the apps as well as summaries of their widget usage in *ContextChat* and their heart rates per message in *HeartChat.* The interviews were then transcribed and analysed and discussed by two researchers using *Thematic Analysis* [5]. Finally, two researchers looked at the arising coding tree and established the emerging themes from the interview data.

To facilitate recall of interesting situations during the interviews, we employed different additional methods. In *HeartChat*, we prepared plots showing the group's heart rate time series over the course of the study. This allowed us to ask people about interesting patterns, thus connecting quantitative measurements with qualitative feedback and experiences. This also helped participants to recall moments which were of interest in the chat and scrolling through conversations to check out the situation and reflect on it. In *TapScript*, we implemented an in-app feedback button that was always visible in the chat view. It allowed participants to take screenshots of the current chat. The button was explained at the beginning of the study. During the interviews, we asked people to check their screenshots (privately) and, if they liked, to verbally share or show us what they had 'collected'. Both the *HeartChat* plots and the *TapScript* screenshots resulted in feedback on several additional situations that would likely not have been remembered otherwise. Hence, we recommend to prepare usage logs and to provide quick 'note-taking' features in prototype apps to facilitate later interviews.

Besides general experiences and feedback, for *TapScript*, we asked questions about aspects such as perceived influence of font adaptations on both typing and reading text, explicitly influencing the font, interpreting adaptations, reacting to them in the conversation, and recognising chat partners based on fonts. Reoccurring themes in the *TapScript* interviews were relationship/personal, interpreting (implicit) adaptations, using explicit adaptations, influences in contexts (e.g., subway), and performance/legibility. These aspects were mentioned in the interviews for all five groups.

In the interviews conducted after the *HeartChat* evaluation, we asked users about their particular messaging experience using the different views of *HeartChat* over the two weeks. We inquired about particular situations that the participants shared with us, how they perceived and reacted to the shared heart rate information and how their usage of the heart rate augmentations has evolved during the two weeks of use. The analysis of the interviews showed the following four main recurring themes: empathy and awareness, heart rate sharing and everyday topics, self reflection through personal messaging, and understanding heart rate augmentation.

Specific interview questions in *ContextChat* addressed usage situations and usefulness; (in)adequate situations for sharing/receiving context information; relevance, also compared to the message itself; interest in specific cues; and talking about the context in the chat. Main themes in the *ContextChat* interviews were correctness of context information, privacy, specific usage situations and interpretation and inference.

3.2.3 Data Logging. To complement the feedback from questionnaires and interviews, our prototype apps logged usage data, described as follows: in all three projects we logged the number of messages per participant, with timestamps; in *ContextChat*, we further counted the uses of the chat/detail views, and recorded the occurrences of each type of context information; similarly, *HeartChat* logged the use of each of the three different modes, as well as the (sent) heart rates per message; and *TapScript* offered the 'feedback' button mentioned above that allowed participants to make screenshots of notable moments.

3.3 Summary of Results

In this section, we describe the results from our three projects. We provide a summary of quantitative and qualitative results from *TapScript* and *HeartChat* (for details see *TapScript* [8], *HeartChat* [21]). We provide more detailed results for *ContextChat*, since this evaluation has not been published *a priori.*

3.3.1 TapScript [8]. On average, participants created 44 messages per person over the course of the week. One group continued to use the app for three weeks. The app was used in a range of situations, like at home, on the go, at work, while eating, running and on day trips. The study showed that *TapScript* allows for expressive typing in chats. Based on the interviews, the handwritten look was associated with individual, intimate and casual use. On the other hand, it was potentially less legible than usual fonts. Adaptations were remembered related to specific situations, which sometimes had become a topic in the chat (e.g., asking about a subway ride, which showed in a very shaky font). Triggering adaptations explicitly was explored out of curiosity and for creative effects. Implicit font variations were accepted as part of the handwritten look as long as they stayed understandable and subtle. Several people asked for more direct control over adaptation settings and strengths for some situations. Overall, people liked to exchange messages in their personal fonts, which were perceived as distinguishable between users and basic contexts. This was also supported by our survey ($N = 91$, see [8]), in which people looked at screenshots of *TapScript* messages: they distinguished pairs of typists with 84.5% accuracy, and walking/sitting with 94.8%.

3.3.2 HeartChat [21]. On average, participants created 289 messages per person during the two weeks of the study. The app was used in many different situations including at home, at work, on the go, during physical activity and during holidays.

The heart rate modes questionnaire conducted at the end of the study showed that the *HeartButton* mode (Figure 2, right) was considered the clearest and easiest to interpret. *HeartBubbles* (Figure 2, left) was considered the most fun and enjoyable to use, allowed partners to understand each others' states, and makes them feel connected. Through the analysis of the ABCCT questionnaire *HeartChat* proved that it provides benefits such as emotional expression, engagement and play (scoring > 2.5 on the benefits scales). It also showed that it scored better on the costs scales than market chat applications.

The thematic analysis of the interviews illustrated the different themes of usage of *HeartChat*. *HeartChat* encouraged and supported empathetic interactions and awareness. Participants mentioned that *HeartChat* triggered them to ask their partners how they were feeling and enhanced their awareness of the state of their partners through the shared heart rate. In addition, *HeartChat* helped participants reflect on their own heart rate and adjust personal goals (e.g., playing more sports). *HeartChat* acted as a subtle cue for chat partners to identify each other's physical context and helped interlocutors feel more connected.

3.3.3 ContextChat. Since this study has not been published before, we report on it in more detail here. Overall, 27 people participated in our study (13 female) with a mean age of 26 years (range: 16–43 years). Participants were recruited via a university mailing list and social media in groups of two to three. Six groups were couples, four were friends, and one group was friends and family. They used their own phones.

Overview. Each participant on average sent 69 messages with our *ContextChat* app, opening the chat view 109 times, and the detail view 32 times. In total, 78% of all detail views were opened in the first week of the study. Participants reported that they used our chat app in different contexts, such as at home, on the go, at work, at university, in (public) transport and on a holiday trip.

Not every message had every context widget: music depends on the users' listening behaviour; distance and weather require a recent GPS measurement; and activity is only shown if Google's Activity Recognition API returned an activity with a high confidence value. Thus, overall 11.9% of messages were augmented with music context, 58.6% had activity context, 62% showed the chat partners' distance and 82.2% displayed weather data.

When asked in the interviews, 14 people stated they paid more attention to the text than to the context information; eight people stated the opposite and five said they paid equal attention to both text and contexts. Overall, people found the context hints interesting and enjoyed using them; they, in particular, liked distance and music contexts. Although participants liked the general concept of automatically augmenting text messages with context hints, most focused on specific context types when reporting what they liked about the concept. Hence, we next focus on the results for the different context widgets.

We summarise the main results from the *Context Widgets Questionnaire* (see Table 1) per widget below. For each widget, we only consider the ratings by people whose groups actually shared messages with said context at least once during the study. Additionally, we summarise the feedback from the interviews, as well as further results.

Music context. The music context widget occurred for 24 different songs by 7 users. Note that not everyone listened to music on the phone, and only 41% had a Spotify premium account to play received music directly within our app.

In the questionnaire, 61.1% found sending songs relevant, 83.3% found it interesting, 66.7% agreed that the sent music information was correct, 77.8% thought it was good to share music with others and 55.6% would have preferred it to manually choose whether to send music. Hence, music was the most interesting context based on these ratings, although it was only used in a minority of the messages (11.9%, see overview section above).

This also showed in the interviews: 16 participants said that the music context widget was their favourite one. Two said they could infer their chat partners' activities based on the received music (e.g., relaxing, working). Four people mentioned that the music widget allowed them to discover new songs via their friends.

The interviews also revealed that for some people songs were sent even after they had finished playing, explaining the partial disagreement with correctness in the ratings above. This was due to missing media broadcasts in some music player apps. On the positive side, several participants highlighted music regarding their connection to their chat partners. Two people explicitly mentioned a feeling of connectedness. Others reported they had sometimes sent empty text messages just to share their music with their chat partners.

Distance context. Regarding sending distance, 68% rated it as relevant, 80.0% found it interesting, 72.0% thought it was correct and 68.0% thought it was good to share it. Moreover, 76.0% would have preferred it to manually choose whether to share distance. Thus, according to these ratings, distance was the second most interesting context and it occurred in more than half of all messages (62%, see overview).

Our interviews revealed that people particularly liked the dynamic aspect of distance information: they could follow distance changes, for example, as a chat partner was moving towards them over time. Three participants mentioned the possibility to use distance information to more easily meet with nearby people. Two of them did so during the study. Another pair of participants used distance to estimate how long it would take one partner to arrive at home.

On the other hand, distance was the context with the most comments regarding privacy. Participants speculated on possible scenarios of misuse, such as stalking or issues arising from discrepancies between displayed distances and where people themselves claim to be in their messages (e.g., distance too large to match a 'I'm at home' statement). It was also questioned if distance was less privacy invasive than actual location, since the latter might be inferred, for example, from a known distance to someone's home.

Activity context. A minority found sending activity to be relevant (19.2% agreement or strong agreement with 'It is relevant for me to send this information'). Reported in the same way, 30.8% found it interesting, 42.3% agreed that the sent activities were correct, 42.3% thought it was good to share this information and 80.8% would have preferred it to manually choose whether to send this information or not. According to this number, activity was the least interesting context, and the one for which manual control was desired most. It appeared in more than half of the messages (59.6%, see overview). Looking at occurring activities in detail, the most common one was *still* (66.1%), followed by *tilt* (16.4%) and *walking* (2.2%). Both *running* and *on bicycle* did not occur at all.

Comments in the interviews explain the low ratings in the questionnaire – the activity provided by the used API was often incorrect. For example, five people reported wrong detections of *in vehicle*. Moreover, the meaning of each activity type might not have been clear to everyone; in particular, some people associated tilt with shaking the device, possibly due to our choice of the icon (see Figure 3).

Despite these drawbacks, participants reported making use of activity context. For example, one group described that they used activity to find out if someone was at home or on their way. In general, activity was more interesting to participants when at least one person was on the go, compared to everyone being at home.

Weather context. Finally, sending weather data was rated as relevant by 23.1% and as interesting by 34.6%, while 61.5% rated the data as correct. In total, 38.5% thought it was good to share weather data and 57.7% would have preferred it to manually choose whether to send it. With these ratings, weather was one of the two less interesting contexts for our participants, although it occurred most often (82.2%, see overview) and 12 people said that it was among their favourite ones. Six participants clarified that they only found it interesting if there was a considerable difference between weather/temperature at their own location compared to their chat partner's.

Interviews revealed that at least two people misunderstood the weather context – they thought that the device itself (and not a web API) would measure temperature and might thus be able to infer if someone is indoors or outdoors. Three people reported that weather data sometimes had been incorrect, while four others said it had been correct in the study.

Participants used weather information in a variety of ways. One person better understood the partner's mood because the widget had indicated bad weather. Another person said the weather widget helped them to convince their chat partner that it was really as cold as they had said in the chat. Another participant reported sending back home a message with a particularly high temperature during a holiday in Greece. Finally, two people sometimes utilised this context widget to get current weather information, similar to using a dedicated weather app.

4 DISCUSSION

Throughout the three presented projects and their evaluations, we gained insights into text message augmentation regarding a wide range of aspects. Here, we discuss the following four major themes that have emerged, in particular, from the interviews: (1) privacy, (2) correctness and understandability, (3) intimacy and connectedness and (4) inferring context. In addition, we reflect on our employed methodology. This discussion leads to the design space presented at the end of this article. Figure 4 provides a visual overview of the main themes and discussion points.

4.1 Privacy

Throughout our projects, we gained insights into several privacy-related aspects of message augmentation, discussed here: social relationships, social norms and pressure, and special situations.

4.1.1 Social Relationships Dominate Privacy Concerns. In *TapScript*, handwritten-looking adapted fonts were perceived as personal and casual. Hence, as mentioned in the interviews, font personalisation was seen as more suitable for chatting with friends than with business partners. *ContextChat* confirmed this view: here, sharing contexts was mostly seen as unproblematic with friends, family, and partners – but study participants said that they would not want to share contexts with their boss or strangers. While we did not specifically investigate such other

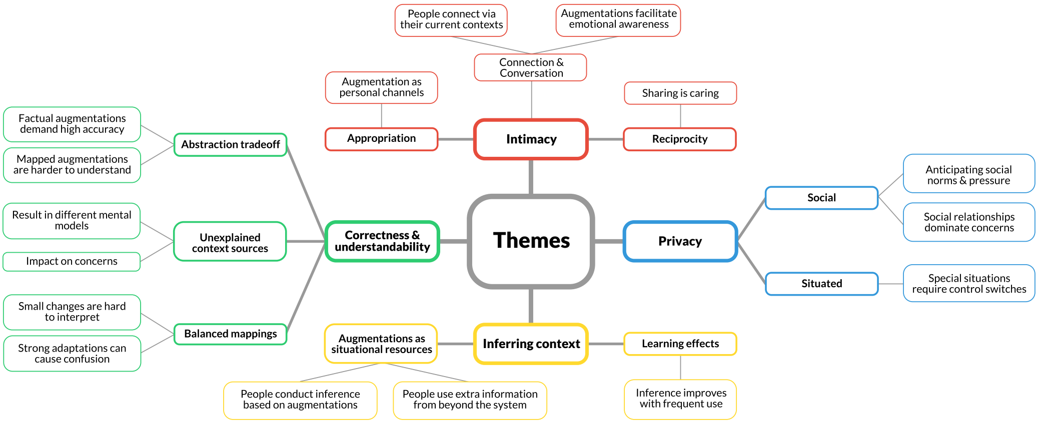


Fig. 4. Overview of the main themes and discussion points.

relationships, participants' views in all the three studies indicate that people do not want to use augmented text messaging with everyone.

Similarly, people did not mind sharing heart rate via *HeartChat* with their loved ones and very close friends. However, sharing this data with their colleagues, boss and sometimes even family was viewed as problematic in some cases. Participants sometimes stated that they prefer sharing only positive information. Similar to emoticon sharing [69], they thus also viewed heart rate as an indicator for positive or negative valence, or health issues. This also confirms findings from prior literature [22].

These results match the findings of related work on context-aware phone call applications [28], where social relations also played an important role for the disclosure of personal context information. More generally, our findings agree with Walther's work on *selective* self-presentation in mediated communication [67, 68], which he found was affected by factors like the interlocutor's gender and status.

4.1.2 People Anticipate Social Norms and Social Pressure. Multiple participants of the *HeartChat* study stated that their critical views on sharing heart rate might change if it would become a norm to do so. In this case, they said, they would not mind sharing heart rate any more – as long as mutual sharing is always the case. This seems comparable to, for example, the introduction and adoption of the *received and read* check marks option in WhatsApp, which is only displayed if the user shares their own status, too. In contrast, explicitly negative views on developing such norms were stated as well, namely in comments on social pressure.

Social pressure was mentioned in interviews on both *HeartChat* and *ContextChat*. A few people described the feeling that if context augmentation is available in a chat app, users have to keep it enabled. Otherwise, chat partners might think that they have something to hide. In this regard, correctness of context information was seen as highly important to avoid misunderstandings. Social pressure was not mentioned for *TapScript*, likely because font adaptations convey context only implicitly. Nevertheless, in principle, social pressure might arise for the use of implicit context cues like font adaptations as well.

4.1.3 Special Situations Require Control Switches. Even with trusted chat partners in casual conversations, there are situations in which some context augmentations should be switched off to avoid revealing unwanted information. For example, one person disliked that *TapScript*'s font tilt indicated to her friend that she was currently lying down. Similarly, people in the *ContextChat* interviews also described situations in which they would like the option to turn off certain contexts. In particular, they wanted to control if others could infer whether they are at home or not. Additionally, several people found it inadequate or embarrassing to share certain kinds of music, in particular in certain situations (e.g., at work).

Control could be provided per context or in general. Here, work on context-aware telephony [28] found that people selectively removed contexts instead of disabling all of them. We did not study this, but received comments suggesting both control models. Another way for providing control is to let users confirm and modify automatically suggested contexts [14, 61]. Following the notion of 'plausible deniability' [32], users could also be given control over the accuracy of context information [9].

4.1.4 Summary and Implications. In summary, the chat partners' social relationships dominate privacy concerns. This indicates that systems should offer sharing settings per chat partner or for groups of people. Additionally, our field studies showed that there are everyday situations in which people would like control options to (temporarily) switch off certain – or all – context augmentations. Finally, a possible development of social norms and social pressure should be anticipated when designing such systems; in particular, when they become more widespread in the population.

4.2 Correctness and Understandability

Ideally, all displayed context would be easy to understand and correct all the time. Unfortunately, this is difficult to achieve in practice; for example, due to limited accuracy of inferred context. In our projects, we gained insights into people's expectations and their reactions to varying understandability and incorrect context data.

4.2.1 Factual Augmentations Demand High Accuracy. People were more lenient towards context presented in a processed, highly abstracted manner compared to augmentations presenting less abstract, raw or factual data: *ContextChat*'s factual presentation with low abstraction resulted in high expectations with regard to correctness; showing a precise number implies more accuracy than, for example, a subtle highly abstracted visual change in *TapScript*'s fonts. Moreover, factual presentations like displaying a numerical distance, temperature, or a specific activity are often easy to verify.

In consequence, participants easily noticed and criticised incorrect augmentations of low abstraction. This in turn negatively impacted on perceived usefulness and interest for the corresponding context data. In particular, the least accurate context in *ContextChat* (activity) was also rated the least interesting one.

In contrast, no one considered *TapScript* fonts as 'incorrect' or inadequate, although it did not completely match people's actual handwriting, presumably, since it was not perceived as a context fact due to the high level of abstraction from context to font. Moreover, it was accepted since it still succeeded in better representing the individual person than a normal font. We made similar observations for context-based font adaptations. In our field study, many (movement) contexts were observed that could not be distinguished from font distortions alone. Nevertheless, most participants found the adaptations interesting – not imprecise or incorrect – and sometimes sought more information by asking their partners directly about the situation that had changed the font.

HeartChat covers a middle ground. Part of the concept showed heart rate explicitly without abstraction (i.e., *HeartButton* mode), yet it is more difficult to verify these values than, for example, checking the temperature. In our interviews we found that participants trusted the heart rate values from the sensor and considered them to always be correct. After several days of usage, *HeartChat* participants were more aware of their normal heart rates and began to take more note of any abrupt elevations of declines.

4.2.2 *Mapped Augmentations are Harder to Understand.*

The overall picture is reversed for understandability. Here, context mapped to an indirect, highly abstract representation is harder 'to get right' than factual representation with low abstraction. For example, some users of *TapScript* wondered how exactly the system had adapted their fonts, in particular regarding font distortions based on finger placement. Slight font variations were accepted as part of the handwritten-look. If they sometimes became too strong, people were surprised and wondered why their fonts had been distorted.

Similarly, some participants in our *HeartChat* study had trouble understanding smaller heart rate changes when using any of the two colour modes. Most found the colour scheme to be intuitive, but noted that it changed slower than expected. This impacted on their understanding of the colour coded heart rates, compared to the numerical values shown in the factual, less abstracted mode.

Finally, our *ContextChat* study showed that factual cues can also become hard to understand if they suffer from low accuracy, as can be expected. For example, the 'device tilted' and 'still' activities occurred too randomly for some participants to develop an understanding of their relationship to the users' real actions.

4.2.3 *Unexplained Context Sources Impact on Mental Models and Concerns.*

If it is not clear from which sources context data is taken, this has consequences beyond the technical level. For example, two people thought that *ContextChat*'s shown temperature was measured by the device itself. They, thus, worried that temperature could be used to find out if they were at home or outside. While temperature was actually retrieved via a weather API, this case shows that understanding the background of context annotations is relevant for the user; for example, with regard to privacy concerns.

4.2.4 *Observations on Degrees of Context Changes and Visual Mappings.*

Our results show that context changes of different sizes and balancing visual mappings are two important factors that designers and developers need to consider to facilitate understandability and/or to guide interpretation.

As is known about heart rate as a physiological signal, it can indicate physical activity or emotional arousal. Participants in the *HeartChat* study found it easier to understand the physical context of their interlocutors than their emotional context. Emotional arousal reflects in more subtle increases/decreases in heart rate, which were not easily detectable in colour changes.

Furthermore, *TapScript* revealed the challenge of striking an understandable balance of mapping functions from signal to visuals: participants reported cases of both too strong adaptations (e.g., tilt while lying on the side), and too subtle ones (e.g., no clear influence of typing speed). While we can address this by tweaking parameter settings, feedback indicates that users themselves also would like to control these mappings to some degree.

Beyond continuous values, mappings are also important for categorical contexts: *ContextChat* represented activities as icons (e.g., 'tilt' in Figure 3). Here, feedback suggests that additional explanation is important, at least initially. This was part of our detail view (Figure 3(b)), which according to our logfiles was mostly opened in the first week of the study.

4.2.5 *Summary and Implications.*

Our results show that designers face several central tradeoffs regarding understandability and required accuracy of message augmentations: factual representations with low abstraction raise expectations on accuracy and correctness, compared to mapping data to more abstract representations. The latter, however, are harder to understand than explicitly stating context facts. Moreover, some sources of integrated information require explanation to avoid that users develop incorrect mental models. Finally, mapping signals to visuals requires careful balance. Small effect sizes are generally more difficult for users to interpret. Yet amplifying them is difficult, if stronger effects are present, too. Moreover, indirect subtle adaptations that become too strong can cause confusion about their origins.

Our results show that correctness and understandability influence perceived quality and usefulness of message augmentations. Relating back to our insights on privacy and social pressure, achieving exact factual correctness might not always be desired, and systems might rather give users options to stay vague. Related work discussed this idea as 'deliberate imprecision' [9]. These interlinked factors thus highlight the importance for a systematic design approach, which we aim to facilitate with our design space presented in this article.

4.3 Intimacy and Connectedness

Another reoccurring theme in our studies and interviews was feedback that can be related to aspects of empathy, intimacy and connectedness. We next discuss several facets of this topic.

4.3.1 People Appropriate Augmentations as Personal Expressive Channels. According to Walther's model of computer mediated communication [67, 68], people utilise properties of interface and channel to shape impressions on the receiver's end with a desired outcome in mind. We observed several examples of this in our studies, in particular regarding creating more intimate connections.

For instance, one person added little hearts to their *TapScript* font's 'i', replacing the dot. One group created their own personal 'secret code' by swapping characters in the base font (e.g., drawing an 'e' in place of an 'a'). The emoji drawing feature was also liked and used for more personal expression. More generally, people highlighted the fonts' increased expressiveness and creativity. Many also mentioned the possibility to recognise their chat partners based on their fonts.

Comparing *ContextChat*'s automatically annotated context types, music stands out as the one that can be influenced most directly by the individual person. Indeed, the music widget was appropriated as a custom channel: some people said they had sometimes sent messages just to share their music.

Presumably, this behaviour was facilitated by the close relationships of our participants. Appropriations might look different for other chat partners, such as colleagues.

Overall, these observations fit to known motivations in personalisation behaviour [40], in particular, autonomy and relatedness – people (re)defined augmentations involving their emotions and identities, turning the feature into 'their' technology. Finally, our findings fit well to related work on interpreting awareness cues [41], which concluded that such cues serve as a medium for active expression of ideas and emotions, and that they can be appropriated to this end.

4.3.2 People Connect via Their Current Contexts. Aspects of connectedness are evident in several comments in the interviews, in which people remembered specific situations indicated by the added context information.

In *TapScript*, for example, one person recalled wondering if their chat partner had fallen or dropped the phone after noticing a sudden strong font distortion. Another group chatted about one partner's subway ride, after the font had indicated shaky movement.

We also found that people can conduct explicit 'context inquiries', for example, via *ContextChat* – here, one person reported that she had sent a message to her partner to see via the activity context if he was still on his way home ('walking' activity).

Moreover, context might also be used to plan conversations: Two *ContextChat* users suggested that activity could be considered for deciding when to (further) chat with someone. In *HeartChat*, multiple users suggested that they could figure out if their chat partner is speeding up at a certain time in the day (e.g., at 5 pm after work) and so infer that they are probably trying to catch a bus. This led them to pause the conversation and plan to resume it when the person is on the bus, which they also knew from the colour/number referring to their heart rate. Related work has investigated this specific idea in more detail [42].

Here, we only investigated context sharing in remote scenarios. Ellis et al. [17] discussed groupware systems with regard to a time/space matrix. In that view, our exploration of context augmented mobile text messaging includes aspects of both synchronous and asynchronous communication, yet focuses on distributed communication (i.e., partners are not co-located while messaging). However, co-located settings and other types of relationships (e.g., colleagues) could be explored as well.

Overall, utilising context augmentations for planning, as well as connectedness and reassurance about other's well-being, matches findings in related work [41], which relates them to the notion of *social presence*.

4.3.3 *Chat Augmentations Facilitate Emotional Awareness.*

People considered the displayed context with regard to mood and emotion, demonstrating empathy and emotional awareness.

This was particularly prominent in *HeartChat*, likely, since heart rate is most directly linked to a person. People said that they either asked their partners how they were feeling, or that they were aware of the other's feelings or state through the shared heart rate and the chat. This also led to actions in the chat – sharing heart rate helped people to calm down their chat partners when they were angry. Moreover, it informed them when their partner was excited about something, which in turn triggered conversations. In *ContextChat*, one person better understood the partner's current mood because the app had displayed rainy weather at that time. Similar to our findings, related work on online chats reported that people were interested in knowing if their partner was nervous [70], using augmentations based on physiological sensors.

4.3.4 *"Sharing is Caring".*

Increased intimacy, awareness and empathy resulted in situations in which chat partners expected reciprocity. For example, one *HeartChat* participant said that he had sometimes expected the same heart rate changes from his friend. In addition, two groups stated to feel like 'soulmates', and that they are in sync, looking at their heart rate summary plots in the exit interview. This raises the question whether heart rates of two remote chat partners could synchronize.

Mutual sharing also played a role for other augmentations – per definition, distance is the same for both chat partners in a one-to-one chat. *ContextChat* interviews suggest that people's common but changing distance over time can remind them of their connection, for example, when one person is away on a holiday, or in particular on the way towards the other one. More generally, reciprocity is also indicated by people's very similar ratings for both sender and receiver roles per widget in the *Context Widgets Feedback* questionnaire.

In contrast, some contexts were seen as especially interesting if they are shared yet *different* for the chat partners. For instance, six people using *ContextChat* mentioned that sharing weather data was most interesting if it differed between them. Moreover, four people liked to receive different music from each other in order to discover new songs.

Overall, these findings also fit well to the concept of 'phatic interactions' [65] – casual communication systems like our chat apps often serve to maintain human relationships. Thus, users benefit not only from shared information, but also simply from the act of exchange itself.

4.3.5 *Summary and Implications.*

Our projects provide several insights into the ways chat users relate additional data on user and context to their interpersonal connections.

First, our results show that augmenting chats and thus giving users new possibilities to influence their conversations allow them to find individual expressions for specific chat partners. Second, both implicit and explicit context information can spark conversation and inquiry about the chat partners' current situations. Third, people make use of the displayed context information to assess, understand, and react to their chat partners' emotional states. Finally, the bidirectional exchange of such cues facilitates feelings of connectedness.

In consequence, to support intimacy and connectedness, chat augmentations should provide mutually shared information, including differences and changes, via which people can connect. Augmentations allow for creative adaptations and ways of using them, if they can partly be (re)defined by users themselves, possibly per chat partner. Alan Dix describes 'guidelines for appropriation' [15] that seem to fit well to chat augmentation in this regard, and that could be considered explicitly when exploring future designs.

4.4 Inferring Context

Since chat augmentations only provide a small peek into a user's whole current context, it is not surprising that people try to reason beyond them. This occurred in all projects, discussed as follows.

4.4.1 People Conduct Inference Based on Augmentations. In all projects, we observed aspects of social inference through technology [42]. People utilised given context augmentations to inform actions, and to infer additional information or information on a higher semantic level.

For example, participants of the *ContextChat* study tried to infer their chat partner's location based on the distance, including observing changes in distance over time. In two cases, music was used to infer the partner's current activity (e.g., working, relaxing). One group utilised the activity widget to find out if someone was at home or outside. Another user tried to assess her chat partner's mood based on the weather.

Similarly, participants used *HeartChat*'s heart rate as a subtle and implicit cue to determine each other's context. To guess their partner's location or activity, they often referred to the colours from *HeartBubbles* or *HeartLight*, together with time and date.

Our *TapScript* survey [8] showed that people accurately distinguish walking from sitting based on the adapted fonts. Moreover, in the field study several situations occurred in which users tried to infer their chat partner's context, for example, based on font distortions related to a subway ride, lying down, falling or standing up.

This observed inference behaviour also fits to Don Norman's discussion of 'storytelling' as an implication of humans' integration of cognition and emotion [38]: humans are predisposed to look for causes of observed events, here shown contexts. Combined with the stories of others, here shared via text messages, they learn about how people behave. In summary, we conclude that augmented chats provoke human inference since they bring together (1) a (chat) partner to learn about, (2) context events that trigger reasoning and (3) a platform for people to share their stories in addition or reaction to those events.

4.4.2 Inference Improves with Frequent Use. Our results suggest a training effect for inference based on chat augmentations: in particular, with regular use of *HeartChat* over the two weeks of the study, several participants were already aware of their partner's whereabouts or activities at certain points of the day if they sent messages.

They often combined this information with heart rate to predict an upcoming interruption in the conversation (i.e., running to catch a bus). Participants mainly used the *HeartBubbles* or *HeartLight* views to gain such contextual insights, since colour coding allowed them to see the bigger changes in heart rate due to physical activity. Moreover, five people using *ContextChat* mentioned that they had become more aware of their relative locations through the distance widget. In addition, one group reported that they had learned to map specific reoccurring distance values to concrete frequently visited locations.

These results match related work on context information for phone calls [28]; here, people also combined different context sources with background and social information to infer another person's situation. According to other related work [43], the existence of awareness cues increases habitual 'checking' behaviour. Combined with our results, this presents an explanation for improved inference over time: users gain experience from frequent comparisons of cues and otherwise known information (e.g., social background).

4.4.3 Summary and Implications. All three of our studies consistently show that people try to infer additional information, sometimes in quite creative ways. To do so, they also incorporate information from beyond the system, like known habits. As such, their reasoning improves over time with continued use of the augmented chat applications.

The fact that users conduct inference based on chat augmentations should be considered when developing such systems. We see two main issues that can be related to privacy and user experience (1) successful user inference can leak information that *a priori* seemed unshareable to designers and possibly to users themselves, initially (e.g., location inferable from other contexts and social knowledge); (2) unexpected (incorrect) user inference could lead to misunderstandings (e.g., someone concludes, possibly incorrectly, that their partner is not at home).

In general, related work on social inference [39] describes that designers of 'cues' have little control over these, since they form situational resources, which people combine with many others to inform their actions. Following the related work and our findings, we highlight the importance of employing a user-centred design approach. This should in particular include field deployments of at least a week, since user inference occurs in everyday situations and improves over time with continued use.

4.5 Limitations

4.5.1 Sample Limitations. Most of our participants were recruited via channels related to the university. Our sample is thus biased towards students and a certain age group (ca. 20–30 years, see Table 1). Therefore, the results might not generalise to the wider population. Furthermore, we focussed on assessing participants' experiences and views. A larger sample would be useful to complement this with more quantitative measures and testing (e.g., to further compare the *ContextChat* widgets). Moreover, most groups of participants were friends or partners. Future studies could extend the observation to further social relationships, such as messaging with family members and co-workers – in particular, since our participants already speculated about different behaviour for such groups. As another aspect, our sample included both (1) groups who saw each other regularly in their daily lives and (2) people living in different countries (see *HeartChat* study [21]). Future research could investigate this aspect in detail. For example, the motivation and use of context cues for inferring each other's situations might vary. Finally, while we covered different group sizes (2–4 people, see Table 1), future work could explore the use of chat augmentations in larger group conversations (e.g., a dozen people organising a party).

4.5.2 Limited Prototype Functionality. With regard to ecological validity, ideally participants would use their usual messaging apps in the studies. However, all our studies use prototype apps, since the novel features and data logging cannot be integrated by researchers into popular proprietary apps on the market. This has at least two effects as follows: (1) people draw (implicit) baseline comparisons and (2) limited functionality may affect experiences. We discuss this in more detail as follows.

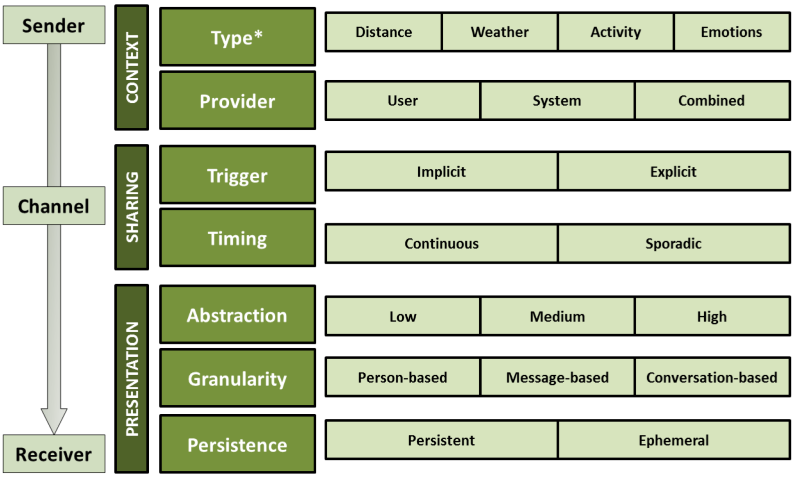


Fig. 5. Design space of augmented mobile messaging. Three core dimensions are defined: Context, Sharing, and Presentation. Sub-dimensions are shown in the figure and (*) indicates that we only show examples of possible context types, not an exhaustive list. To the left, the figure also shows how the design dimensions relate to the flow of information from sender via channel to receiver.

First, when introducing a prototype app for a study ‘in the wild’, the goal is to (at least partly) replace participants’ usual messaging apps for the duration of the study. Hence, participants tend to view their usual apps as a general baseline (e.g., regarding features and user experience). To evaluate novel concepts, it is useful to assess users’ comparative views as well. Beyond feedback in the interviews, we aimed to compare aspects like user experience and affective benefits and costs via questionnaires (*AttrakDiff* in *TapScript*, *ABCCT* in *HeartChat*, see Table 1). Our experiences show that this comparison via questionnaires is difficult and rarely yields actionable insights. A problem is that participants need to carefully separate concepts from prototype implementation. Hence, we recommend to include comparisons like these in interviews, for example, asking users about newly tested features in particular. Here, it is easier to trace answers back to conceptual differences vs. technical ones.

Second, well-known apps on the market are more polished and feature-complete than research prototypes. For example, people often mentioned that they would like to send images and videos and see their usual friends list. This introduces some limitations: for example, we do not know how *TapScript*’s fonts or *HeartChat*’s heart rate information would be used and perceived in combination with sending pictures/videos. Moreover, if combined with other media, some of the cues might become less interesting (e.g., weather data vs. picture of the sky) or rather richer (e.g., played song plus video of user dancing). On the other hand, limited functionality may help to focus on basic usage and experiences with sending text. Nevertheless, future studies could investigate sending context cues combined with other media. Finally, researchers could re-use and extend prototype apps from prior work, building more complete research tools throughout the community (cf. frameworks for mobile logging, such as *AWARE* [19]).

5 DESIGN SPACE

Through our three presented chat apps, literature and market applications review, and our discussion of findings in the previous section, we chart the design space of the augmented messaging applications. Figure 5 shows an overview of the design space. The design space also shows the vertical flow of augmented information in a messaging application from the sender, through the channel, to the receiver. The following sections present the different dimensions and sub-dimensions of the design space, including examples from our projects and the literature. We discuss how the dimensions and the space overall can be used to help designers and developers in designing augmented chats that increase awareness, connectedness and expressiveness.

5.1 Context Types

In our earlier presentation of context and context models, we have presented various kinds of contextual information that can be communicated. Most encompassing to our work, Sigg's model of context [57] divides context types into six top level dimensions: Identity, Location, Time, Activity, Constitution and Environment. These dimensions and subdimensions of context can all be used to augment chats.

Through our three applications we gathered a lot of feedback about the utility and understanding offered by different contexts. For example, in *ContextChat*, sharing music and relative distance were found to be the most interesting, informative and fun to use. In *HeartChat*, numerical heart rate (*HeartButton*) was considered to be a rather clear and straight-forward way of communicating physical activity contexts. Colour changes in both *HeartLight* and *HeartBubbles* conveyed affect, physical activity and also acted as a subtle cue for location. In *TapScript*, activity context was inferred from changes to the user-defined handwritten-looking font. Handwriting itself – as a personal user attribute – was considered to be more intimate and personal than a regular font.

Beyond the contexts in our studies, other potentially interesting information was suggested in the focus group during the design phase of *ContextChat*. These include system-based context, such as battery level, more precise activity definitions like reading or studying, other open apps, current scenery (e.g., at the sea), calendar appointments, current social interactions and emotions. Some of these contexts have been investigated in prior work, as discussed in the related work section. However, with the advent of sensing technologies, further contexts can be researched in order to assess their utility in a messaging application.

5.2 Context Provider

Different contexts can be *sensed* via system sensors, or *user-defined*, or a combination of both. *HeartChat* used a heart rate sensor directly connected to our app. In *ContextChat*, smartphone-based sensors and external APIs were used to extract the context information. In *TapScript*, the primary context provider was the user, who initially provided a handwritten font by drawing with the finger on the screen. This font was then adapted by the system to communicate sensed context.

While almost all messaging applications allow users to set a status and to send emojis as ways to define and share context, various applications also provide other contexts such as location, mood and activity. For example, Facebook allows users to define their current mood, to check-in at a current location, or to share their activity, illustrating another example of user-based context providers.

Messaging applications on the market today also include system-defined contexts such as changing online status after a period of inactivity, or implicitly detecting locations via GPS-based phone sensors. More recently, Whatsapp and other mobile chat apps introduced the *received*, *writing* and *read* message cues, which are all provided by the system.

Although system-based context providers reduce manual efforts on the user's part, they can also suffer from lack of trust or questionable correctness. They might also be perceived as privacy-invading, and may raise ethical questions. We reflected upon these issues in our discussion section.

5.3 Sharing Triggers

Sharing of sensed and augmented chat information can either be *explicit*, approved and done by the user him/herself, or *implicit*, directly triggered by the system once the information is available. Explicit sharing, for example, via a button, gives the user complete control over shared data and time of sharing. Implicitly triggered sharing directly sends the augmented/sensed information to the chat partner without interference from the user.

Both *HeartBubbles* and *HeartLight* modes implicitly shared the heart rate. On the other hand, the *HeartButton* mode provided a button to explicitly trigger sharing of heart rate. In *ContextChat*, all contextual widgets were implicitly shared per-message. In *TapScript*, sharing was also done implicitly per message.

While current market applications allow users to first explicitly set if they would like to share contextual information (e.g., online status in Whatsapp), the application then goes on to implicitly share the information after giving initial consent (e.g., in a settings view). Most research artefacts and prototypes also investigated implicit sharing as a way to lower the load on the user (see, e.g., [34, 36, 47, 64]). However, completely automated sharing can hinder users to exploit plausible deniability [32]: for example, a system might automatically disclose a user's current activity, although that user does not want to share reasons for not answering messages.

5.4 Sharing Timing

Context information can be either shared *continuously* or in a *sporadic* manner. Continuously shared contexts are updated in real-time by their context providers. Sporadically shared contexts can be sent or updated, for example, upon the press of a button, after a pre-defined time interval, or when special events occur (e.g., a sudden increase/decrease or change in the contextual information).

HeartChat's *HeartLight* view shared the heart rate continuously, updated at 1Hz. Continuous sharing can act as an additional information channel unrelated to the message context. However, it can also be overwhelming and redundant with extra information that is not too important to be shared at the time.

In all three applications we explored sporadic sharing. In the other two modes of *HeartChat*, *ContextChat* and *TapScript* context was sent with each message. Sporadic sharing provides information in a discontinuous manner. This can be done when a user prefers to precisely poll the sensed context and share it a particular moment, for example, via a button press, like *HeartButton* mode in *HeartChat*. Sporadic sharing may be also triggered when a change in status or context is detected, for example, when the user's activity detects a change from being walking to seated. We have not investigated this form of sharing through our application, however, we envision that it is an interesting direction for designers to consider.

5.5 Presentation Abstraction

Context data can be abstracted in different ways for representation in the chat application. Here, we discuss examples of low, medium and high levels of abstraction, depending on the context that the designer intends to communicate.

Low abstractions are *raw* representations; they often show context information directly as it arrives from a sensor. For example, in *HeartChat*'s *HeartButton* view, heart rate was shown as number of beats per minute. Other cues with low abstraction include precise numerical representation of sensor data from accelerometers and gyroscopes. As another example from our projects, in *ContextChat*, temperature was shown numerically in the detail view (Figure 3(b)).

Context information can also be mapped to colours, icons, other visual indicators or auditory cues [37], moving away from the raw level. Note that the level of abstraction highly depends on the intended communicated context. For example, if facial expression data is collected via a context provider (e.g., webcam) and mapped to facial expressions on an avatar, we regard this as a low abstraction level. However, the same data translated to *emotions* and presented as text (e.g., happy, sad, angry) is a high abstraction. Our aim with these abstraction levels is not to define a strict classification, but to provide a guideline for designers to consider different abstractions for representation.

In *HeartChat*, both *HeartBubbles* and *HeartLight* modes mapped heart rate to a colour range instead of showing it in a raw numerical format. We place this representation at a medium level of abstraction; not raw but on a scale. *TapScript* adapted fonts to communicate context, most prominently movement. We consider this mapping from sensor readings to font distortions, an example of a high level of abstraction.

ContextChat used a mixture of low and medium level abstraction presentations. In the message view, icons were used to illustrate activity and weather, and an icon was added to the numerical representation of distance. The cover image of the current music was also shown. In the detail view, both raw information as well as iconic representations are shown side by side, presenting an example of a mixture of different abstraction levels. Backed by our results, such combinations seem useful to (initially) help explain the representations.

Reflecting on advantages and disadvantages, we find that raw representations on a low level of abstraction are easy to understand, for example, showing heart rate numerically, or using a textual representation of activity. However, there are exceptions: physiological signals (heart rate, GSR, EEG, etc.), in particular, are highly individual. Thus, more abstracted/interpreted representations can better include a normalisation procedure to allow for easier comparisons and understanding [21]. Moreover, beyond a basic level of interpretation, it can be hard to try and follow the meaning of (multiple) raw physiological signals over time.

In general, adding many (possibly similarly represented) context types might become overwhelming or at least distracting, especially, for a GUI that has to fit a small screen used ‘on the go’, as on mobile phones. As a compromise, systems can use a combination of raw and interpreted representation as details on demand, such as the message view and detail view of *ContextChat*.

5.6 Presentation Granularity

The augmented information can either be *person-based*, *message-based* or *conversation-based*. In *TapScript*, personalised keystrokes are sent per message, as they are an inherent part of the text message itself. *ContextChat*’s context widgets are also message-based, namely, annotated at the bottom of each message. In *HeartChat*, both *HeartButton* and *HeartBubbles* modes show heart rate information per message. However, the *HeartLight* mode shows heart rate information per person.

As instant messaging is a social activity, researchers also investigated representing context information in an overall *conversation-based* format, where each person in the chat contributes to the general atmosphere [47].

5.7 Presentation Persistence

Context information in the chat can be presented in a *persistent* (i.e., lasting) manner, or *ephemerally* (i.e., temporarily). Ephemeral messaging has been introduced in the past few years and gained a significant amount of attention after the success of the app *SnapChat*[5]. In this app, messages only persist for a small amount of time before they entirely disappear, providing a more private and playful experience.

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[5] Snapchat: https://www.snapchat.com/, accessed February 2017.

Table 2. Overview of Augmented Text Message Systems from Research Projects in Our Design Space (Context Types Omitted)

Project	Provider	Trigger	Timing	Abstraction	Granularity	Persistence
Fabri et al. [18]	System	Explicit	Sporadic	Low	Person	Ephemeral
HeartChat HeartButton					Message	Persistent
Viegas and Donath [66]				High		Ephemeral
Rovers and van Essen [49]						
Tat and Carpendale [63]					Conversation	Persistent
Shin et al. [56]					Person	Ephemeral
ContextChat Detail View		Implicit		Low	Message	Persistent
ContextChat Conv. View				Medium		
Kaliouby and Robinson [16]						Ephemeral
Tsetserukou et al. [64]				High		
Dimicco et al. [13]						Persistent
Iwasaki et al. [27]						
Zhiquan Yeo [72]						
HeartChat HeartBubbles						
Pong et al. [47]					Conversation	
Lee et al. [34]			Continuous	Low	Person	Ephemeral
Kuber and Wright [31]						
Hong et al. [23]				High		
Isacs et al. [26]						
Wang et al. [70]						
HeartChat HeartLight						
Kienzle and Hinkley [29]	User		Sporadic	Low	Message	Persistent
TapScript	System & User			High		
Rangathan et al. [48]		Explicit		Low	Person	Ephemeral

Our own projects from this article are *highlighted*. The table shows the dimensions of the design space that are thoroughly covered in research and these which are still open for further exploration.

Persistent context presentation gives a lasting overview of the history of the conversation that users can go back to and check at any point in time. In our three applications, except for the *HeartLight* mode in *HeartChat*, the augmented information was always persistent.

Prior research looked into various ways of representing persistent and historical augmentations post-hoc; in other words, after the interaction has finished [62, 63]. Other applications only showed the augmented information (e.g., heart rate) ephemerally during the chat conversation [34].

5.8 Examples of Using the Design Space

Our design space enables a structured approach for creating new concepts and ideas for chat augmentations. The space also helps to systematically reflect on prior work in order to identify underrepresented augmentation approaches. Table 2 gives a (non-exhaustive) overview of how related work and our own projects cover our design space. In the following, we outline three ideas for future systems and research as examples of using the design space for guidance.

5.8.1 Interacting Avatars. Looking at the design space covered so far (Table 2), we could explore the novel combination of user-provided and triggered context with both person- and conversation-based granularities. Here, a new concept could aim to display *emotion*, which is *provided by the user*, shared *explicitly* and updated *sporadically*. Emotions are represented on a medium level of *abstraction*, namely mapped to the facial expression of a user-created avatar shown in the chat *per person*. The avatar reflects the user's last set emotion, overwriting previous ones – an *ephemeral* representation with no history. However, further arranging the avatars of the chat partners according to their (relative) moods adds a *conversation-based* element; for example, if one user is happy but the other one is sad, their avatars could be arranged in a 'cheer you up' posture. If two partners feel accomplished, their avatars might 'high five', and so on. Based on our findings, this concept could cater to the observed creative interest in user-defined augmentations (setting up an avatar), as well as connectedness (avatars' interactions), while providing a high level of user control and correctness (shared emotions set by users).

5.8.2 Continuous 'brb'. Along our design dimensions, the related work shown in Table 2 reveals the opportunity of combining explicit triggering with continuous sharing. Considering this, we suggest a continuous 'be right back'(*brb*) feature. Mobile chat conversations are often interrupted by people's daily activities. Context augmentations could support keeping track of another person's interruption. A user goes shopping, for example, and *explicitly* sets a 'be right back' status. Now, the *system* uses GPS, activity recognition and calendar entries to provide *continuous* updates about the missing *person* to the chat partners. For instance, a small progress indicator could count down an expected time or publish cues such as 'at the shop' and 'heading back home', possibly via icons. Regarding our findings, this concept aims to facilitate social presence (live updates of missing person), and considers user inference (chat partners can follow along, thinking about what happens at the moment) and control (explicit trigger).

5.8.3 'What Happened So Far'. Finally, this concept covers the under-represented combination of sporadic conversation-based augmentations that stay persistent in the chat view itself.

TV series and multipart movies often provide short summaries of previous events at the beginning of a new episode or after a break. Inspired by these summaries, we envision a concept that *implicitly* presents chat partners with an overview of each other's activities – *sporadically*, when returning to a *conversation*. This content could be provided by the *system* (e.g., GPS data), as well as *users* themselves (e.g., event attendances from calendars and social networks). For example, such a summary could include context statements with *low abstraction*, like *'Max has travelled 500 km since your last chat'*. To potentially serve as kickstarters for (continuing) a conversation, these 'what happened' messages are *persistent* parts of the normal message history. Considering our results, this concept targets interest in mutual context sharing and feelings of connectedness and awareness. It also suits mobile checking habits [43] by showing what has happened since the last 'check' of the conversation.

6 IMPLICATIONS ON DESIGNING FOR AUGMENTED CHATS

With our discussion of the three augmented chat applications, as well as the resulting design space, we aim to facilitate the design of augmented mobile messaging applications. In the following, we summarise on a metalevel our derived recommendations and implications in relation to our design space.

6.1 Context

Expect that augmentations reveal more than the selected contexts. Designers may select certain contexts for their augmentations and avoid others, for example, to conform with privacy standards. However, users interpret augmentations combined with information from beyond the technical system. The extent of these inference processes is hard for designers to fully anticipate *a priori*. In addition, users' reasoning improves over time with continued use, for example, as they discover their chat partner's habitual augmentation patterns. To assess user inference and the augmentations' actual extent of communicated information, we thus recommend a user-centred design approach, including field deployments of at least a week.

Incorporate user input to facilitate appropriation and creativity. Augmentations that can be defined and interpreted more freely by users themselves allow for creative use (see Dix' 'guidelines for appropriation' [15]). Hence, we recommend to particularly consider user-provided information and/or self-defined representations to support users in establishing their own expressive channels, also per chat partner, to facilitate intimacy.

6.2 Sharing

Offer sharing settings based on social relationships. The social relationships of chat partners are at the focus of privacy concerns related to contextual text message augmentation. We thus recommend to offer sharing settings per chat partner and for groups of people (e.g., friends, colleagues).

Provide a control switch. There are everyday situations in which people would like to switch off certain – or all – context augmentations. To address these user needs, settings should offer control switches, possibly including a master switch, to (temporarily) turn off (some) augmentations.

Consider combining user input and automatic augmentations. Incorrectly derived context negatively impacts user experience, in particular, for automatically added augmentations. Hence, we recommend to consider options for users to review and confirm added contexts before sending their message. This could also include methods to revise or remove the automatically derived context information. Systems can also learn from users' behaviour and automatically correct previously altered augmentations.

6.3 Presentation

Choose factual presentations for easy understanding of parallel robust contexts. Factual presentations raise high expectations on accuracy and correctness, but are generally easier to understand correctly. We thus recommend to favour representations with low abstraction if context information is correct and accurate. Moreover, using multiple subtle parallel mappings might overshadow each other and/or confuse users.

Ensure that highly abstract representation mappings stay subtle. Abstract mappings from context to representation can cause confusion if visual effects become too strong, since their origins are often difficult to understand, and users might therefore not share the designers' conceptual model of the involved processing and mapping steps. Thus, if context data is mapped to rather indirect representations (e.g., mapping movement to font distortion), we recommend to ensure that the visual effects stay subtle, compared to other augmentations.

Show context changes over time to facilitate awareness. People are particularly interested in context changes and often react to them directly, if they notice any. To facilitate awareness of such changes, we recommend persistence. Showing historical context values makes it easier for users to notice and react to changes over time.

Focus on current context to highlight reciprocity. Bidirectional exchange facilitates feelings of connectedness. Hence, we recommend ephemeral augmentations to emphasise concurrent mutual 'live' sharing, and to highlight similarities and differences between the chat partners' contexts at the current moment.

6.4 Tradeoffs of Context Augmentation

Building on these implications, we reflect on different tradeoffs from the literature on awareness systems as well as our presented work. In particular, we observed results in line with the dual tradeoff between awareness and both privacy and disturbance [25], and a general tradeoff between automation vs. control [9, 32]. We found two main directions of interconnected tradeoffs along those dimensions.

The first direction favours manual control instead of automation for sharing and providing context information. This goes well with concerns about privacy and social aspects such as plausible deniability, as well as checking and updating cues for correctness. Additionally, user input may support appropriation and creativity. On the other hand, manual configuration and intervention potentially increase disturbance and workload, which may lead to users abandoning these features or systems.

In contrast, the second direction favours automation, letting the system provide and share context data with little to no user intervention. This augments text messages with context without increasing the required user effort while chatting. On the other hand, the system's sharing decisions might not always be aligned with the user's intentions, causing problems related to privacy and social expectations. This might be amplified by (predefined) mappings from raw sensor data to more abstracted representations, which already introduce a certain perspective of interpreting the data.

7 CONCLUSION

Text messengers are among the most popular communication applications on mobile devices today. However, text messages lack expressiveness and awareness in comparison to face-to-face conversations. A chat partner's situation is difficult to understand if not described explicitly in the messages. At the same time, a few existing context hints and the popularity of emojis indicate users' interest in sharing more than text itself. Technically, modern mobile communication devices and additional wearables offer a range of built-in sensors that may be used to assess context. This provides rich opportunities for augmenting mobile text messages with context.

This article has explored and reflected on such opportunities as well as challenges. In particular, we discussed insights and methodology based on three field studies with prototype chat apps [8, 21], including user-defined and sensor-based chat augmentations, and additional wearable (heart rate) sensors. Our deployments probed into different augmentation approaches for various kinds of context 'in the wild'.

Evaluations including group interviews, questionnaires and usage data analyses revealed people's behaviour, understanding and concerns regarding four major themes of text message augmentation: privacy, correctness and understandability, intimacy and connectedness, and inferring context.

Based on these insights, we discussed lessons learned and charted a design space for augmented text messaging. Finally, we concluded with design implications to inform future work on text message augmentation. With our contributions, we hope to inspire and facilitate systematic investigation of ideas to improve expressiveness and awareness for users of mobile text messaging.

8 FUTURE WORK

Our projects reveal several interesting areas for future research.

In all the three studies, people's feedback included aspects of increased control over text message augmentations. As stated in the implications, such controls should at their minimum consider social relationships and include on/off switches. Beyond that, future work could also investigate options for users to review, change, or remove augmentations. Furthermore, it is an open question how to best integrate such control methods into augmented chat applications.

Besides control aspects, utilising further data sources, sensors and devices offers wide avenues for future work. Systems could also combine more (of the existing) data sources and augmentations. For example, we could combine *HeartChat*'s heart rate with *ContextChat*'s activity context. Such combinations might become more than the sum of their parts, as we have seen that users naturally combine different information sources to infer their partners' contexts. Future work can also consider the online status of chat partners to show or hide the contextual augmentations. In a recent exploration of messaging applications, Podlubny et al. introduced the Curtains Messenger that only allows sending/receiving messages and checking out old messages if both chat partners are online [46]. In case of contextual augmentations to allow for more transparency and control, the same aspect can be explored, similar to *HeartChat*'s HeartLight view, but instead also for message related contexts.

As more and more information is considered, it will likely become urgent to comprehensively investigate related trade-offs between displayed context information and distraction from the text messages. *ContextChat* received mostly balanced ratings in this regard, yet this may change as more context augmentations are added.

Text messages could also embed context in further dimensions of how they are displayed, for example letting text appear letter by letter in the writer's heart rate, or changing the font based on weather data.

Finally, we encourage further investigation of other forms of chat messaging beyond one-to-one. Group chats have become a mainstream way for users to organise and schedule events, keep in touch with old colleagues, or quickly broadcast requests and gather information, for example, in a workplace. Considering the design dimensions with regard to augmented group chats presents an interesting opportunity for further research. For example, presenting augmented information to groups might lead to other privacy issues, or might be too distracting and overwhelming depending on the size of the group. We believe that designers and researchers should, thus, further investigate these types of text messaging beyond one-to-one communication.

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