Supporting Peripheral Perception in Distributed Teams by Enforced Exposure to Chat Messages

Miroslav Novotný and Valentino Vranić

***Abstract*—Members of colocated teams benefit from being able to peripherally perceive ongoing conversations separating the useful information from the rest of the ambient sound. Instead of oral communication, distributed teams usually rely on chat. We developed an approach to supporting peripheral perception in distributed teams by enforced exposure to chat messages and implemented it as a chat client for Slack. The idea is to expose the team members to receive messages in order to emulate natural peripheral perception of oral communication that can be observed in colocated teams. We assessed how well enforced exposure to chat messages supports peripheral perception by following communication intensity, message relevance, and distraction in two experiment settings: content-based and periodical message displaying. The experiments were performed with four student teams in a week to two weeks' time span. Seven team members had our chat client installed, while the rest of them (14) did not and used the unadapted chat clients they commonly use. The experiments were accompanied by a survey. Overall, enforced exposure to chat messages was perceived positively by the participants, especially in content-based message displaying. Communication intensity was clearly higher there, too. A strong correlation between the distraction caused by enforced exposure to chat messages and the communication intensity has been confirmed.**

***Index Terms*—Agile software development, communication intensity, distraction, distributed teams, peripheral perception, work context.**

I. Introduction

SOFTWARE development is intrinsically collaborative with direct human communication being indispensable. Studies have shown that almost 70% of software development time is spent on collaborative activities [33]. Agile and lean approaches, which are constantly gaining more approval and acceptance, among which Scrum is probably the most prominent example, are a practical proof of this. They principally rely on a direct contact of those working on a particular artifact avoiding as much as possible proxies of any kind, be it human or documentational [30]. This is the reason why Scrum teams are expected to be colocated. However, distributed teams are reality and they also seek to benefit from what Scrum and other agile and lean approaches have to offer.

It is important to understand that the kind of communication that needs to be supported in distributed teams is not the one known from organized meetings, but the communication during the day-to-day, hour-to-hour work, often occurring in a purely casual way as a chat among coworkers during their working routine or even when taking a break. Informal communication has been recognized as crucial for success [21], [25], which has been expressed as several important organizational patterns (mined from highly successful projects) cataloged by Coplien and Harrison [9], such as Hallway Chatter, The Watercooler, Group Validation, Unity of Purpose, or Shaping Circulation Realms. It has been observed that people actively seek for collaboration outside the prescribed boundaries of pair programming, a common agile software development practice, spending as much as 20% in extra-pair communication [34].

A particularly interesting part of informal communication happens via *peripheral perception* of what others say, write, or show. By just being exposed to information, a developer or other stakeholder unconsciously and effortlessly adopts it.[1] Subsequently, this information dramatically improves effectiveness and efficiency of direct communication and other work activities as it provides a common work context, which accounts for the large part of the success of agile and lean projects [13]. This includes awareness of the presence of other team members, their work on the project, information about team members, awareness of the common working environment, etc. A rich common work context in a team adds to mutual trust, work morale, and work efficiency [4], [19]. Cockburn's Osmotic Communication, as one of project management strategies [6], which can be viewed as another organizational pattern, probably best corresponds to peripheral perception. Like in chemical osmosis, immersed in information, people tend to absorb what they need. For a full concentration, people sometimes need a complete isolation, i.e., the opposite to Osmotic Communication, which Cockburn calls Cone of Silence [6]. It is worth mentioning that

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[1]Note that *peripheral perception* as used here is not related to the notion of peripheral vision [3].

Cone of Silence around Osmotic Communication, i.e., putting a team together in a room and leaving them alone to do their work, is probably the most effective way of dealing with small-scale agile projects [6]–[8].

While the probability of communication between team members is high when distances are small, it rapidly decreases if the distance between them is more than 10 m [19]. In the case of a distributed environment, when it is not possible to use direct communication, information and communication technologies can be of help.

The rest of this article is organized as follows. Section II indicates that a peripherally perceived conversation within ambient sound can be a useful source of information. Section III proposes an approach to supporting peripheral perception in chat. Section IV identifies an experiment space for reasoning about the usefulness of peripheral perception in chat and what affects it. Section V presents the results of the actual experiments performed with respect to this. Section VI discusses the results of the experiments. Section VII compares the approach proposed in this article to related work. Finally, Section VIII concludes this article.

II. From Ambient Sound to Information

During their work activities, people are never utterly isolated from ambient sound. Silence may have healing effects on a human being [12], but absolute silence may cause discomfort as much as noise [28]. A certain level of ambient sound (also known as environment sound or even noise) appears to be natural for a human being [16]. Thus, what is actually considered as silence is a certain tolerable level of sound containing noise produced by surrounding people, machinery, weather conditions, animals, plants, etc.

Whether the sounds are perceived as disturbing depends on many factors. In her paper on noise in an office workplace [29], Maxwell claims that the ideal work environment sound intensity is 48–52 dB. This sound level can be compared with a sound intensity of a silent conversation or to the noise of a street without heavy traffic. Maxwell also claims that working in a loud environment (55 dB and more) has negative effects on both mental and physical health. People are very sensitive to sound during work that requires concentration and memory usage. Different types of personality perceive background noise differently [14], [35]. For example, as Doyle and Furnham discovered, while extroverts perceive music positively during their work, introverts are distracted [14]. However, these experiments were performed with music, not with what one would really call noise. Generally speaking, decreasing noise in a working environment can be considered as beneficial, but certain amount of noise is acceptable and natural, and not harmful. This speaks in favor of not isolating team members from each other to allow them to benefit effortlessly from the information contained in what is considered as environment noise. Team members use peripheral perception to access this information.

A conversation can merge with ambient sound beyond the possibility of recognition, but it can also step out from ambient sound and bring some information [17]. In a team, this information can affect the recipient and finally be beneficial for the whole team. In his paper about nautical navigation, Hutchins points out the importance of gaining information by a team member from a communication among other team members [22].

Thus, an unintentional, peripheral perception of ambient sound can turn into an intentional following of a conversation or even joining it. Triggers to this depend on what is important to the percipient, but hearing one's own name can be singled out as a general trigger. It has been demonstrated that upon identifying one's own name, observable brain activities comparable with brain activities when describing own personality or personal qualities take place [5]. Other triggers free from the personal context are based on the capability to distinguish sentence types despite their contents not being fully comprehensible.

III. Supporting Peripheral Perception in Chat

Much of the communication in distributed teams happens via chat. It has been demonstrated that receiving and answering text messages during work activities is causing disruption and recipients may experience difficulties in resuming in their work activities, although the impact of chat communication on work efficiency and on time of task completion is not critical [26]. This may be due to people being used to chat. According to another research, chat communication has positive effects on work efficiency when solving simple tasks, whereas when solving complex tasks, the effect of chat communication is not very positive [1]. Mensi and Levy proved experimentally that chat affects time needed for both complex and simple task completion [27]. However, Davison and Ou in their work regarding chat distraction proved experimentally that the chat communication has positive effects on communication quality and trust among team members while distraction is not significant [31]. According to their findings, chat communication has an effect of around 5% out of all work environment distraction. Also, unlike face-to-face communication, messages can be turned off if necessary.

The information from chat communication may substitute both direct and indirect oral communication in distributed teams. Group chat is of particular importance here, since it comes close to the natural oral communication present in colocated teams. In a group chat, even those participants who do not post their own messages benefit from the discussion. This happens even if they do not follow the discussion intentionally, which is a kind of peripheral perception.

We developed an approach to supporting peripheral perception in distributed teams by chat and implemented it as a chat client for Slack which—unlike Slack—enforces the exposure of the team members to received messages. These are the messages accessible by the team members, so no privacy issues arise. Furthermore, our chat client is limited to following only messages in one channel selected by the user.

There are several considerations in emulating peripheral perception known from oral face-to-face communication in distributed teams using chat. To mimic not hearing everything said and keeping participant from becoming overwhelmed, some messages need to be dropped, i.e., message has to be displayed

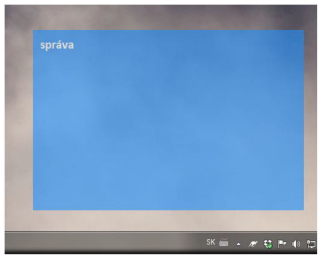

Fig. 1. Displayed message.

conditionally. This may be based on whether the message contains the participant's name or whether it contains a particular phrase or word important to the participant.

People also start perceiving communication when they notice a change in voice tone or intensity. This usually happens when question or imperative sentences occur. In our application, this phenomenon is emulated by displaying messages containing symbols ? and ! to the recipient. These symbols may be also used for different purposes, but we assume that in the majority of cases they will be used to indicate a sentence type.

The phenomenon of not perceiving the whole communication is emulated by displaying just a part of a received message instead of the whole message. By this, a lower level of distraction may be achieved as well. Just as with mishearing, this can also lead to misunderstandings. We did not directly address this issue, but it certainly can be alleviated by embracing semantic analysis approaches.

Selected received messages are displayed for several seconds in a blue transparent window in the bottom right corner of the display (see Fig. 1). This is similar to common Slack notifications, but the window is bigger than Slack notification windows because the purpose is not to notify the team members of messages, but to expose them to the message content. The window is transparent to cause less distraction. The white text color was chosen for its high contrast to the blue background in order to make reading easy. While choosing the most appropriate colors is an issue in itself, and may be heavily affected by individual preferences, this was not part of our research.

IV. Usefulness of Peripheral Perception in Chat

According to what we learned so far, it is reasonable to believe that it would be useful to embrace peripheral perception in chat. However, it is not obvious how really it would be useful to do so, nor how the selection of the messages the recipients should be exposed to affects the usefulness of peripheral perception. In order to reason about appropriate experiments in this context, we first mapped the overall experiment space with respect to the capabilities of our chat client (Section IV-A), and then identified the most interesting experiment settings (Section IV-B).

A. Experiment Space

The feature model of the experiment space displayed in Fig. 2 contains all the features that can be used to create specific experiment configurations. We used feature modeling in the basic Czarnecki–Eisenecker notation [11]. A feature can be included in a configuration if its parent is included and if its inclusion obeys variability constraints: mandatory features must be included, optional features can be included, exactly one alternative feature in a group must be included, and at least one or-feature in a group must be included.

Messages are displayed (*Displaying*) either completely (*Whole Message*) or partially (*Message Part*), with the part to be displayed can be a selected number of words from the beginning of the message (*First m Words*) or selected number of words following a given word (*First m Words After a Word*).

Message selection (*Message Selection*) may be based on time (*Periodicity*), on the text the message contains (*Text*), or on syntactic constraints (*Syntax*). Time based message selection may be expressed in terms of how often messages are to be displayed (*Every nth Message*) or, alternatively, how often messages are to be omitted (*Skip Every nth Message*).

Message selection according to their meaning can be based on whether they include certain phrases (*Phrases*), which will usually be used to describe the work context, or whether they include certain keywords (*Keywords*) somehow relevant to the user, like the users name. Both phrases and keywords are supplied to the application.

Syntactical constraints (*Syntax*) are currently limited to detecting interrogative and exclamation sentence types based on whether messages include exclamation or question mark (*Sentence Type*).

B. Selected Experiment Settings

Our chat client supports all possible configurations of the experiment space feature model presented in the previous section. Out of these, we selected two particularly interesting experiment settings: content-based message displaying (see Fig. 3), for being close to the peripheral perception of oral communication, and periodical message displaying (see Fig. 4), for its randomness in message selection, which also occurs in natural peripheral perception of oral communication.

V. Performing the Experiments

Since a more intense communication may be expected to increase peripheral perception, but not if messages are not relevant and if they cause too much distraction, we have chosen to assess how well enforced exposure to chat messages supports peripheral perception by following communication intensity, message relevance, and distraction.

We measured communication intensity as a number of messages received per minute. For a team, we consider communication intensity to be an average of the communication intensities of individual team members, counting with only those team members that actually participated in the communication. More formally stated, communication intensity CI_t of team t with m members actually participating in the communication is calculated according to the following formula:

$$CI_t = \frac{\sum_{n=1}^{m} \frac{N_n}{t_n}}{m} \tag{1}$$

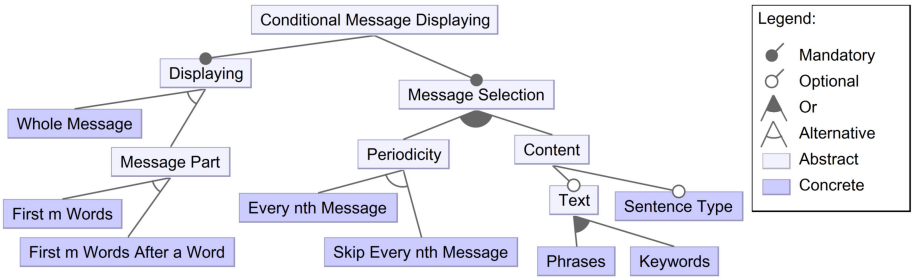

Fig. 2. Feature model of the experiment space.

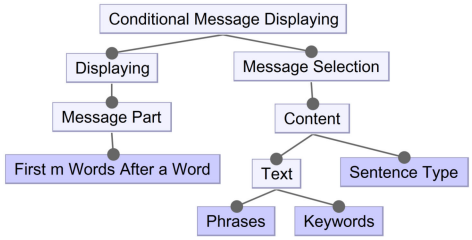

Fig. 3. Content-based message displaying.

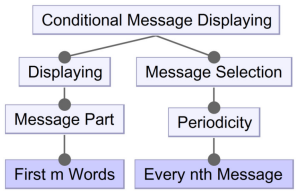

Fig. 4. Periodical message displaying.

where N_n is the number of messages received by team member n within communication time t_n. Communication time does not include silent intervals. We consider an interval between messages longer than 10 min to indicate an end to the ongoing communication segment and the beginning of a silent interval.

A message can be considered as relevant if the recipient performed any actions as a consequence of receiving the information contained in this message. We interpreted this in terms of having recipients join the conversation, this message belongs to or having them perform any change in the artifact on which they have worked at the moment they received the message. We acknowledge this to be a very distant approximation since we do not really interpret the affected artifacts, nor the nature of changes and how they correspond to the actual message contents. However, it may be reasonable to expect that if someone is making changes to artifacts while exchanging messages, the changes are related to these messages (as if the recipient is following some kind of instructions).

If distracted by something, people tend to get rid of the source of distraction. Consequently, we would expect them to have tendency to turn off our chat client if they would be distracted by the messages being displayed to them.

TABLE I
INDICATORS MEASURED IN THE EXPERIMENTS WITH CONTENT-BASED AND PERIODICAL MESSAGE DISPLAYING (SEPARATED BY A SLASH)

Team (number of participating members)	Communication time [min]	Communication intensity [msg/min]	Displayed messages out of the received ones [%]	Clicked messages out of the displayed ones [%]
1 (3)	291 / 773	1.47 / 0.47	39.64 / 37.86	13.38 / 1.23
2 (1)	114 / 17	0.39 / 1.41	43.18 / 33.33	15.79 / 0.00
3 (2)	323 / 517	0.66 / 0.22	52.32 / 45.21	36.50 / 2.17
4 (1)	235 / 248	0.24 / 0.23	32.91 / 38.60	26.67 / 9.10
Weighted mean		0.83 / 0.49	42.01 / 39.42	22.78 / 2.45
Standard deviation		0.55 / 0.56	8.08 / 4.89	10.65 / 4.08

The participants of the experiments were the students attending the *Team Project* course at our university. In this course, students develop software systems in teams according to a given assignment and under the supervision of teachers. Teams consist of four to six members and the team project spans over the whole academic year. Teams work according to Scrum as much as possible since this is not their full-time job, nor they can be colocated all the time. Thus, they act mostly as distributed teams depending heavily on chat communication.

To obtain relevant results, the experiments were repeated with four teams. Seven team members had our chat client installed, while the rest of them (14) did not and used the unadapted chat clients they commonly use. The results of the two experiment settings we ran (specified in Section IV-A) are presented in the following two sections.

A. Content-Based Message Displaying

In the experiments with content-based message displaying, 643 messages were received by the participants from four teams during the total of 1563 min of communication. Table I displays the indicators measured in both experiment settings. To calculate the average values, the weighted arithmetic mean was used. In this, only those team members that had our chat client installed have been taken into account. The high value of the standard deviation was caused by a high communication intensity in the first team.

TABLE II
TRIGGERS IN THE EXPERIMENTS WITH CONTENT-BASED MESSAGE DISPLAYING

Team	Work context [%]	Name [%]	Sentence type [%]
1	63.09	7.38	48.33
2	94.74	5.26	31.58
3	53.85	5.77	17.31
4	90.00	10.00	32.50
Weighted mean	75.42	7.10	32.43
Standard deviation	20.02	2.13	12.67

TABLE III
MESSAGE IMPORTANCE RECOGNITION (NUMBER OF MESSAGE CLICKS) IN CORRELATION WITH TRIGGERS IN THE EXPERIMENTS WITH CONTENT-BASED MESSAGE DISPLAYING

	Average value [%]	Standard deviation [%]
Work context	25.30	16.30
Name	45.71	20.83
Sentence type	22.65	17.83

Message displaying was triggered by the occurrence of work context notions, participants' names, and interrogative and exclamatory sentences in messages. The extent to which these triggers account for message displaying is summarized in Table II. As can be seen, the most frequent trigger was occurrence of work context notions: in 75.42% out of all displayed messages. The sum of percentages of displayed messages per team (not displayed in the table) exceeds 100% because for some messages two or all three triggers occurred simultaneously.

From the standard deviation, we can see that the most significant differences between teams are in the ratio of messages displayed because they contained work context notions. The reason is that participants had a possibility to define their own work context notions. This made the lists of work context notions quite different among the teams. The nature of the project also determines the probability of using particular work context notions in communication. Nevertheless, we can see that messages displayed because they contained work context notions have the biggest ratio in all the teams.

Clicking a message displayed by our chat client brings in its full contents. It can be assumed that a clicked message was recognized as important to the recipient who clicked it. Table III uncovers what kind of trigger made participants recognize messages as important. It shows the ratio of the clicks recipients had on the messages displayed to them. Definitely, mentioning their names happens to be the most prominent reason for the participants to consider messages as important.

To judge the level of distraction by the messages the team members were exposed to, we performed a survey (the questionnaire is available in the appendix). An interesting and slightly unexpected result, at least to that percentage, was that 89% of the participants declared they had no tendency to switch off enforced exposure to chat messages. In order to obtain a more realistic picture of how distracted participants really were, we put distraction in the context of message relevance. The participants had to mark a position that corresponds best to how they felt about the messages they were exposed to in a triangle formed by three extreme possibilities as displayed in Fig. 5. The figure also displays aggregated answers from all participants. This confirms our findings that participants were not very much distracted by the messages they were exposed to and that many messages occurred as relevant to them.

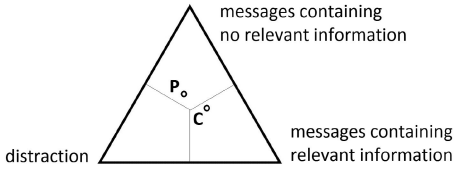

Fig. 5. Aggregated answers from all participants regarding the content-based (point **C**) and periodical message displaying (point **P**).

B. Periodical Message Displaying

The experiments with periodical message displaying were conducted with the same teams that participated in the experiments with content-based message displaying. In total, 401 messages were received by the participants during 1555 minutes of communication.

In these experiments, first four words of approximately every third received message[2] was displayed to the recipient in the same way as in the experiments with content-based message displaying. As previously, the recipients had a possibility to display the whole message by clicking it.

Recall Table I, which shows the indicators measured in both experiment settings. The weighted arithmetic mean of the communication intensity was 0.49 messages/min. Compared with the communication intensity in content-based message displaying (0.83 messages/min), this is significantly lower. The percentage of displayed messages out of the received ones was 39.42%, whereas in the experiments with content-based message displaying it was 41.57%, so the difference is negligible. According to how often the participants clicked displayed messages, we can say that the messages displayed periodically were not recognized as important by the recipients at all. Only 2.45% of displayed messages were clicked by the recipient, whereas in the experiments with content-based message displaying this was ten times as much (22.8%).

The communication intensity was highest again in team 1 as in the experiments with content-based message displaying. The indicators measured for team 2 were obtained from a short and intense communication. Therefore, it significantly differs from data obtained from other teams. The average value of communication intensity is lower than in the experiments with content-based message displaying.

As with the experiments with content-based message displaying, we performed a survey to judge the level of distraction by the messages the team members were exposed to. According to the answers to questions 7–9 (see the appendix), we can say that the level of distraction was slightly higher than during the experiments with content-based message displaying: 67%

[2]This approximation is caused by the delay during the application restart.

TABLE IV
COMPARING HOW OFTEN THE PARTICIPANTS CLICKED MESSAGES (IN PERCENTS)

Teamr number	Clicks in content-based message displaying	Clicks in periodical messages displaying
1	13.38	1.23
2	15.79	0.00
3	36.50	2.17
4	26.67	9.10
Average	22.78	2.45
Standard deviation	10.65	4.08

of the participants declared they had no tendency to switch off enforced exposure to chat messages. We also repeated the triangular assessment question on distraction in the context of message relevance (see the previous section). The aggregated answers, which can be seen in Fig. 5, indicate that, compared with the experiments with content-based message displaying, the distraction was higher and the displayed messages were reprieved as containing less relevant information.

Comparing the results from both experiment settings, we cannot but notice a strong correlation between perceived message relevance and distraction in the sense that a message perceived as relevant is mostly perceived as nondistracting and vice versa.

VI. DISCUSSION

In this section, we discuss the results we obtained in our experiments. Section VI-A focuses on message relevance. Section VI-B treats communication intensity. Section VI-C examines the issue of distraction. Section VI-D discusses the threats to validity of the results we obtained.

A. Message Relevance

Table IV compares how often the participants clicked messages in content-based message displaying and in periodical messages displaying.

The percentage of message clicks in content-based message displaying is significantly higher. The answers to question 1, in which the participants had to express their attitude toward clicking the messages they were exposed to (see the appendix), correspond to this. In three teams out of four, the recipients claimed that they clicked the received message more often.

It is also interesting to look at how the participants perceived the influence the message displaying had on communication and work activities. In their answers to question 2, which was about how often the participants joined the conversation because of a message they were exposed to, 50% of the participants in the experiments with content-based message displaying claimed they did join the conversation, while only 33% of the participants claimed that they joined the conversation in the experiments with periodical message displaying. This can be attributed to periodically displayed messages being more often without any importance to the recipients. According to the answers to question 4, which was about recipient joining the conversation because of displayed messages, it can be said that the participants were joining conversations during both experiment settings. The weighted arithmetic mean of these answers reveals that the participants were joining conversations more often in the experiments with content-based message displaying. The statistical method for difference significance produced a critical value of 2.45, which is lower than the critical base value of 15.43, which, in turn, means that these sets of values do not differ significantly. The values in the answers to question 4 are lower for periodical message displaying in all the teams.

Questions 5 and 6 are related to the influence that the enforced exposure to chat messages had on recipients' work activities. According to the answers to questions 5 and 6, we can claim that the influence of communication emerged from the displayed message is approximately the same in both experiment settings. According to the answers to question 4, as mentioned previously, messages displayed periodically have less influence on work activity during the communication. Thus, messages displayed periodically appear to be less related to the work activities performed by the recipients than those in content-based message displaying. Recipients join the conversations more often in content-based message displaying, but the ongoing conversations have the same influence on work activities in both experiment settings. However, if recipients are joining conversations more often, they gain more information, and the influence of the communication on the work activities is higher.

Although the differences are small, we can observe that, except for question 6, the marks are lower for periodical message displaying. This is supported by the triangular assessment question on the level of distraction by the messages the team members were exposed to combined with message relevance (recall Fig. 5), from which we can see that the information benefit for recipients is lower with messages displayed periodically.

B. Communication Intensity

At the end of the experiment with content-based message displaying, we asked some of the participants that had our chat client installed how did they perceive the application. When asked if the message displaying had a positive influence on communication, a member of team 1 answered: "Clearly yes." Another member of the same team said: "Because of the displayed messages, I communicate more often." A member of team 2 stated: "It was way disturbing, but I would not turn it off." "I quite like content-based message displaying since I am not disturbed by every message," he added. Members of team 3 stated: "Without message displaying I would not communicate with other team members that often. Message displaying warns me about the activity on the channel. content-based message displaying is an interesting idea—it would be nice to work further on this idea. It was sometimes a bit disturbing, but it was not a problem to work." Thus, we can say that the statements provided by the participants were generally positive about enforced exposure to chat messages with some complaints about distraction caused by this. The participants said that message displaying was affecting how often they were joining conversations giving preference to content-based message displaying.

Fig. 6 compares communication intensity in content-based message displaying and periodical message displaying. Except

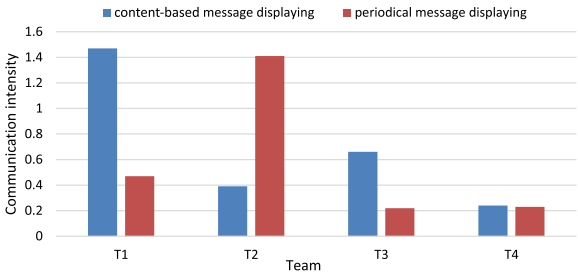

Fig. 6. Average values of communication intensity.

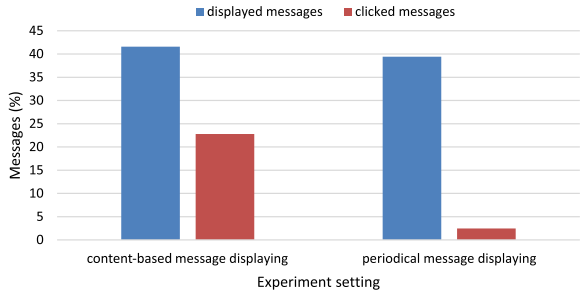

Fig. 7. Percentage of message displaying and displayed message clicks.

TABLE V
QUESTIONNAIRE ANSWERS IN THE EXPERIMENTS WITH CONTENT-BASED (ROWS MARKED BY C) AND PERIODICAL MESSAGE DISPLAYING (ROWS MARKED BY P)

Team		Q1	Q4	Q5	Q6	Q7	Q8	Q10
1	C	1.75	4.00	4.00	3.00	4.25	3.25	2.50
	P	2.20	3.00	2.50	3.00	4.00	3.00	2.50
2	C	2.00	7.00	1.00	2.00	5.00	2.00	1.00
	P	1.00	6.00	1.00	2.00	5.00	3.00	1.00
3	C	2.50	2.25	1.25	1.75	2.75	3.00	3.25
	P	1.50	2.00	1.25	3.00	4.00	2.50	2.50
4	C	2.00	3.50	2.00	2.50	3.50	2.00	2.00
	P	2.00	3.00	2.00	2.00	4.00	3.00	3.00
Weighted average	C	2.03	3.81	2.44	2.44	3.78	2.72	2.38
	P	1.73	3.17	1.75	2.67	4.17	2.83	2.33
Standard deviation	C	0.31	2.01	1.36	0.55	0.97	0.66	0.94
	P	0.54	1.73	0.69	0.58	0.50	0.25	0.87

for team 2, communication intensity was clearly higher in content-based message displaying. However, as we mentioned in Section V-B, the indicators measured for team 2 were obtained from a short and intense communication (recall Table I). Thus, the experiment in Periodical message displaying probably hit the time interval of a more intense communication than the one in the experiment in content-based message displaying. Also, the weighted arithmetic mean of communication intensity is higher in content-based message displaying.

Comparing the communication intensity values (see Fig. 6), displayed message clicks (see Table IV), and answers of the participants about joining the conversation (see Table V) in content-based and periodical message displaying, we can see that the values tend to be higher in content-based message displaying.

C. Distraction

The graph in Fig. 7 shows how often the participants clicked messages compared with the share of displayed messages in both experiment settings. While messages were displayed approximately equally often in both experiment settings, they were clicked considerably less often in periodical message displaying.

This is supported by the average values of answers to the questions regarding recipients' work activities included in our questionnaire. The answers are whole numbers from the interval [1,7]. The higher the value, the higher is the influence of the message displaying on recipient's work activities. As we can see in the graph shown in Fig. 8, periodically displayed messages had lower influence on recipients' work activities.

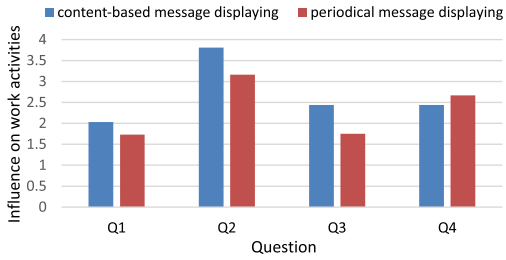

Fig. 8. Influence of enforced exposure to chat messages on recipients' work activities.

The answers to the first question are in line with the values obtained in the experiments. The number of clicks was higher during content-based message displaying. Thus, we can say that the influence of periodical message displaying is smaller. The exception to this is the answers to question 6, which is caused by the fact that this question is related to the number of changes relative to the intensity of the recipient's work activities. Therefore, similar answers to these questions for both experiment settings have been expected.

A tendency to turn off our chat client was also much lower with content-based message displaying. In content-based message displaying, only approximately 10% of the participants said they had a tendency to turn the chat client off, while approximately 33% of the participants wanted to turn off the chat client in periodical message displaying. This is probably because content-based message displaying offered more relevant messages causing less distraction.

The overall correlation between the distraction caused by enforced exposure to chat messages and communication intensity is quite high according to the Pearson correlation coefficient being approximately 0.64. The correlation can also be observed in the graph displayed in Fig. 9. The horizontal axis represents distraction as average marks collected as answers to questions 7 and 8, which are both related to distraction caused by enforced exposure to chat messages. The vertical axis shows communication intensity as a number of received messages per minute. The experiments to which the values belong are indicated in the graph showing a trend line. The coefficient of determination (R^2) of only 0.42 indicates a weaker correlation than the Pearson correlation coefficient.

The correlation between the distraction caused by enforced exposure to chat messages and communication intensity in

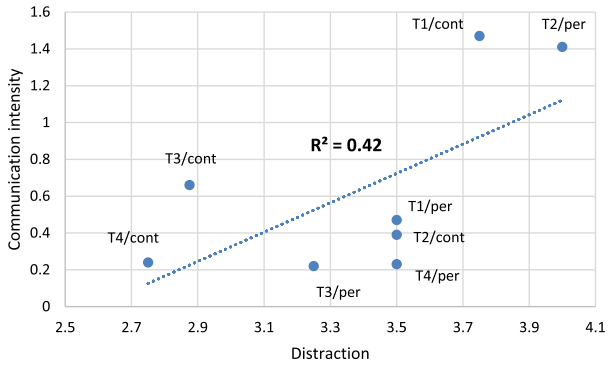

Fig. 9. Overall correlation of communication intensity and distraction in both experiment settings (*cont* stands for content based, while *per* for periodical message displaying).

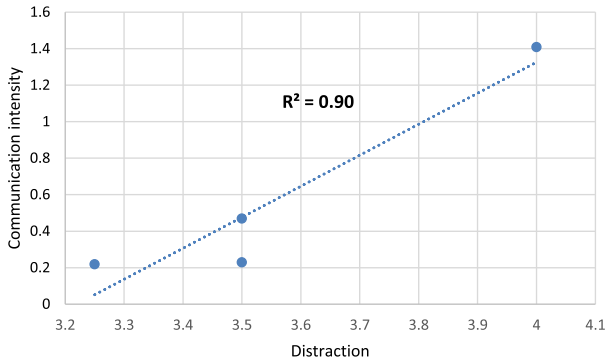

Fig. 10. Correlation of communication intensity and distraction in periodical message displaying.

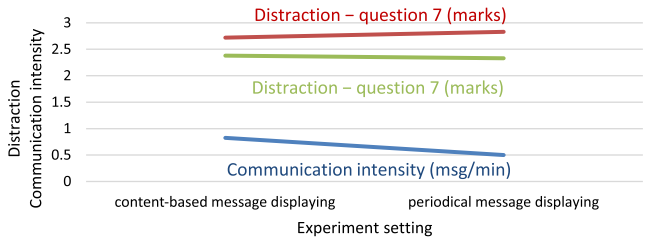

Fig. 11. Distraction and communication intensity.

periodical message displaying alone is even higher with the correlation coefficient being approximately 0.95. This strong correlation is also apparent in the graph displayed in Fig. 10. The coefficient of determination (R^2) of 0.90 confirms the correlation is strong.

As can be observed in the graph in Fig. 11, which compares average values of communication intensity and distraction for both experiment settings, we can notice that with increasing communication intensity, average marks collected as answers to questions 7 and 8 are not much different.

The distraction in periodical message displaying was a bit higher or approximately on the same level as with content-based message displaying, while the communication intensity was lower in periodical message displaying. However, these differences are too small to be of statistical significance.

Mansi and Yair claim that a higher communication intensity does not mean lower efficiency of work activities of the message recipient [27]. According to their experiments, while communication intensity is rising, work activity efficiency is decreasing until a certain moment. From this moment on, despite of the increase in communication intensity, work efficiency is rising, too. This finding may clarify the shadiness of the dependency between communication intensity and distraction in our experiments.

D. Threats to Validity

There are several threats to the validity of the results obtained in the experiments we performed. Gaining the information about distraction only from the survey and not by actually observing the participants is a threat to internal validity that we have not been able to reduce.

The answers obtained from the respondents may have been influenced by their momentary thoughts and feelings, which may have been caused by the previous communication. This also represents a threat to internal validity. However, the majority of the answers correspond to the indicators that we measured over a one or two week period.

A possible dependence of communication intensity on the number of team members represents another threat to internal validity. We managed to reduce this threat by handling the values for each team separately.

The experiment participants being exposed first to content-based message displaying, and only then to periodical message displaying is a threat to internal validity, which could have been compensated by having another group of participants experiencing these two ways of message displaying in the reverse order. However, our intent was primarily to assess how well enforced exposure to chat messages supports peripheral perception overall.

The experiment participants being only students and the fact that the project they were working on is not an instance of actual industrial software development constitutes a threat to external validity. However, the Team Project course is organized so that it approximates the work in real work environment as much as possible. Software systems developed in this course have to be usable and some of them, usually after some additional development efforts, are actually used.

Another threat to external validity is caused by the fact that only four teams participated in the experiments.

VII. Related Work

There are several projects [2], [15], [20], [24] aiming at keeping team members informed of each other's work activities or artifacts they produce. This includes the information about changes and who made them, tasks and who works on them, technologies being used, meeting schedule, availability of team members, etc. Unlike our approach, which relies on general chat communication and peripheral perception, in all these projects,

the information is provided explicitly and commonly by dedicated applications. Nevertheless, it is important to note the positive effects of such information sharing, which, similarly as in our approach, attributes to the common work context building,

Several studies [18], [26], [27], [31] showed that chat communication has positive effects on team work. All these studies agree that distraction effects of chat communication are insignificant, which corresponds to our findings. These studies were based on a common use of chat and, unlike our approach, did not involve any chat client modifications. Furthermore, our intention was not to explore the effects of using chat in general, but only in the context of using it for the purposes of supporting peripheral perception in distributed teams by enforced exposure to chat messages in chat.

In our approach, we have taken a rather simplified view of the work context. Pícha *et al.* took a more thorough treatment of the data available during the whole application lifecycle in an attempt to identify what they call socio-technical patterns [32], which recall organizational patterns [9].

Chat communication is deprived of the nonverbal communication aspects, which are inevitable for transferring emotions and gestures. Emoticons can help to some extent, but they are too simple and artificial to represent complex emotions or gestures. Cornelius *et al.* demonstrated how superior are natural hand gestures over artificial ones [10]. Krcedinac *et al.* experimented with color and graphical representation of emotions generated from text [23]. Our approach could incorporate these or similar ways of transferring emotions and gestures.

VIII. Conclusion

Members of colocated teams benefit from being able to peripherally perceive ongoing conversations separating the useful information from the rest of the ambient sound. Instead of oral communication, distributed teams usually rely on chat. We developed an approach to supporting peripheral perception in distributed teams by enforced exposure to chat messages and implemented it as a chat client for Slack. The idea is to expose the team members to received messages in order to emulate natural peripheral perception of oral communication that can be observed in colocated teams.

Since a more intense communication may be expected to increase peripheral perception, but not if messages are not relevant and if they cause too much distraction, we have chosen to assess how well enforced exposure to chat messages supports peripheral perception by following communication intensity, message relevance, and distraction. We based our experiments on two particularly interesting experiment settings: content-based message displaying, for being close to the peripheral perception of oral communication, and periodical message displaying, for its randomness in message selection, which also occurs in natural peripheral perception of oral communication. We conducted our experiments with four student teams[3] in a week to two weeks' time span. Seven team members had our chat client installed, while the rest of them (fourteen) did not and used the unadapted chat clients they commonly use. The experiments were accompanied by a survey we conducted to better understand the reasoning of the team members exposed to enforced exposure to chat messages.

Overall, enforced exposure to chat messages in chat was perceived positively by the participants. More participants got interested by the messages in content-based message displaying than in periodical message displaying. While the participants were joining conversations during both experiment settings, they did it more often in content-based message displaying. Communication intensity was clearly higher in content-based message displaying. The experiments confirmed a strong correlation between the distraction caused by enforced exposure to chat messages and the communication intensity, which was stronger in periodical message displaying. A tendency to turn off our chat client was much lower with content-based message displaying (10% of the participants), but it was not very high in periodical message displaying either (33%).

We plan to experiment with more sophisticated ways of message selection based on continuous assessment of the work context. This may require access to software artifacts maintained within development environments and other tools. Message selection should not be based only on lexical comparison to the work context. It could be much more precise if it would involve semantics and associative recall. In this, artificial intelligence could play a significant role.

Appendix
Communication Assessment Questionnaire

The questionnaire we used contained the following questions.

1) Did you click a message in the blue window? Assess this by selecting a number in range 1–7 (1—I have not opened any message at all, 7—I opened the message always).
2) Have you joined a conversation after a message has been displayed in the blue window (yes/no)?
3) If you answered yes to the previous question, how did you join the conversation (e.g., by asking a question, providing additional information, etc.)?
4) How often you joined a conversation due to a message displayed in the blue window? Assess this by selecting a number in range 1–7 (1—I didnot join any conversation at all, 7—I joined a conversation after each message displayed in the blue window).
5) How often you changed something in the artifact which you have been working on due to displaying a received message (1—not once, 7—after each displaying of a received message).
6) How often you changed something in the artifact which you have been working on due to the communication provoked by displaying a received message (1—not once, 7—after each conversation provoked by displaying of a received message).
7) Have you had a filling that message displaying is distracting? Assess this by selecting a number in range 1–7

[3]The nature of the study is such that it does not involve sensitive data nor ethical concerns.

(1—message displaying was not distracting, 7—message displaying absolutely prevented focusing on work).

8) Have you been distracted by automatic message displaying[4] to such extent that you could hardly return to your work and work pace? Assess this by selecting a number in range 1–7 (1—message displaying was not distracting, 7—after each displayed message I lost connection to my work activity and it took me a while to be able to continue with work).
9) Have you had a tendency to switch off automatic message displaying (yes/no)?
10) Were messages unrelated to the work activity being displayed in the blue window? Assess this by selecting a number in range 1–7 (1—all messages were related to the work activity, 7—no displayed message was related to the work activity).

Table V shows the results from the survey in both experiment settings for numerically assessed questions. To question 2, 33.3% of the answers were "yes." To question 9, it was 11.1%.

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