Doctoral Dissertation – Academic Year 2017

Enhancing Team-Level Behavior Change Using Information Sharing

A dissertation for the degree of Ph.D.
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Abstract of Doctoral Thesis Academic Year 2017

Enhancing Team-Level Behavior Change Using Information Sharing

Abstract

The rapid spread of smartphones and wearable devices has significantly been enabling activity sensing technologies, and it allows that most people who have the devices, to collect various type of activities in their daily life as lifelog data conveniently. In the ubiquitous environment, the collected data is used for promoting a human behavior in any cases. Besides, the majority of people are spending their most of time in organized groups with their devices.

To the best of our knowledge, existing behavior change researches mainly focused on an individual- or group-level behavior change using lifelog data that is collected by mobile/wearable devices. Moreover, traditional approaches in Social Psychobiology and Behavior Science tackle to analyze human behavior just by observation without dynamic intervention using information technologies. However, most people spend in organized groups surrounded by ubicomp environment in the near future, so that methodologies for empowering the team–level activity is a significant research subject in the organized group in the ubicomp era.

In this dissertation, we designed and implemented *Sapplication Platform* for enhancing and measuring team-level behavior change using information sharing among team members in the ubiquitous environment for the first time. As an intervention method for a team, *Sapplication Platform* can share lifelog data via six types of information sharing models that are based on the "competition" and "collaboration" techniques on existing researches. As evaluations of the platform in this dissertation, we conducted two studies using *Sapplication Platform* over a period of six weeks with baseball- and rugby-team in the university.

Through the evaluations, our analysis showed that the platform could be used in daily activities on real teams. Further, use of the "team-based competition" concept model (*iCL+eCP*) was most effective for teams on competitive teams, such as sports teams, among the proposed models.

Keywords
Life-log, Team, Behavior Change, Information Sharing, Ubiquitus Computing

Keio University Graduate School of Media and Governance
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情報共有を用いたチームの行動変容促進

論文要旨

近年，携帯端末やウェアラブルデバイスの普及に伴い誰もが日常生活中のライフログデータを検知・蓄積可能な環境が整ってきた．それらのデータは今後爆発的に増加すると考えられる．これまで検知された活動情報は，個人を対象とした行動変容の促進に活用されてきたが，今後はスポーツチームや研究のプロジェクトチーム，町内会などの「共通の目標を共有し，その目標達成のために協力できる集団」であるチーム内での活用も考えられる．チームは個人とは異なり内部に様々な人間関係が存在するため，これまでの個人を対象とした行動変容促進手法がチームに対して効果的であるかは明らかになっていない．また，既存研究では，情報技術を用いてチームの行動変容促進を行う研究環境も整備されていない．

本研究では，ユビキタスコンピューティング環境下のチームにおけるチーム全体の行動変容促進の実現のために，スマートフォンを通して収集したライフログデータを,「競争」と「協力」の要素を組み合わせた 6 種類の情報共有モデルを用いてチームメンバと共有可能な，情報共有プラットフォーム（*Sapplication Platform*）の設計・実装を行った．さらに，実チームにおけるプラットフォームの有用性の評価実験として，大学内の 2 つのスポーツチーム（合計 85 名）を対象に，それぞれの短期目標（Sub–Goal）の促進を目標として *Sapplication Platform* 上で 3 週間の実験を行なった．その結果，本プラットフォームはチームにおいて実運用可能であることを実証し，スポーツチームのような日頃からチーム単位で競争を行うチームにおいては，チーム内協力・外競争モデルがチームの行動変容に効果的であることも明らかにした.

本研究の貢献は，ライフログデータの共有を用いたチームの行動変容促進研究分野を開拓した点である．さらに，チームの行動変容促進の実現のために，6 種類の情報共有モデルを提案し，実チームにおける大規模・長期利用を想定した *Sapplication Platform* を設計・実装・評価し実チームにおいて日常的な運用が可能であり，情報共有が与える効果も分析可能であることを明らかにした点である.

キーワード
ライフログ，チーム，行動変容，情報共有，ユビキタスコンピューティング

慶應義塾大学大学院 政策・メディア研究科
西山 勇毅

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Chapter 1

Introduction

In the civilized society, most people live in organized groups such as a school, a company, a family, a neighborhood association, and a sports team for a long time to help each other. Among organized groups, **team** (i.e., sports team, a project team in a company, and a research group in a laboratory) strongly shares a common goal between team members, and they empower each other for achieving the goal. Therefore, to achieve the goal, enhancing the team–level performance is an essentially important factor for the teams.

Ubiquitous computing which is proposed by Mark Wiser around 1988, is a concept of a future computing environment which means that "Computers are existed ubiquitously around human and support human activity calmly." In the ubiquitous computing environment, various types of activity data might be collected without human intentions, and the data is used to enrich human life. Due to the evolution of information technology, the current information environment has been approaching the ubiquitous computing environment. For example, the current development of information technologies such as smartphones, wearable devices, and wireless/distributed sensor technologies (i.e., IoT) have significantly enhanced the ability of humans to capture and record various types of data in their daily lives, examples of such data include the number of steps [1], sleep information [2, 3], foods consumed [4], and communication amount [5, 6]. In addition, the wide variety of such data have been utilized for self–behavior change [7, 8, 9, 10], medical care [11] and social analytics [12, 6].

Under the ubiquitous computing environment, the organized groups assume that they fully use the collected different kinds of data for achieving team goals. However, the valuable data has been still deposited under the user space or each service provider data in the existing researches and systems. The group–level activity enhancement by sharing the data in the groups has a potential to contribute to various group activities for achieving their goal such as improving group–level productivity in companies, an amount of training in a sports team, and contributions of volunteer works in a community. For teams in the ubiquitous computing environment, to investigate methods to effectively use the data are an essential research question.

1.1 The Problem

While existing researches for promoting human behavior change (i.e., Persuasive Computing and Gamification) using interventions by information technologies focused on individual–level behavior change, team–level behavior change has not been investigated yet as best of our knowledge. Moreover, existing computer science researches constructed their systems with several methods and theories such as "competition," "collaboration," and "award." However, effectiveness of the methods and theories have been not clear yet because various kinds of human relationships exist in teams, such as employer–employee, teacher–student, or manager–player, and team goals. In addition, research methodologies for measuring the effectiveness of team–level behavior change and team–level intervention platforms which can apply the team–level intervention methods for the real team generally have not been existed yet.

1.2 Research Goal

The final goal of this research is to substantiating team–level behavior change for achieving their team goal by sharing buried activity data among team members. As applications, the substantiation has a various potential to applying it such as to team–level "productivity improvement," "performance enhancement," and "injury/illness prevention." To achieving the final goal, this dissertation following goals: (1) This dissertation designed and implemented a general information sharing platform for long–term and large–scale team–level intervention. (2) As the first step of team–level behavior change study, this dissertation conducts team–level intervention study using developed platform on real teams, and (3) analyzes effects of information sharing models on the teams.

1.3 Approach

This dissertation proposes Team–level Behavior Change for supporting an achievement of each team goal by circulating the deposed data in a team. The concept of the circulation is called Team–level Behavior Change Cycle (*TBC-Cycle*) which composed of three elements: Team Goal, Team–level Intervention, and Team Performance Indicator. Especially, as team–level intervention, we propose six types of information sharing models that are combined with "competition" and "collaboration" techniques in Gamification.

Moreover, "*Sapplication Platform*" which is based on TBC–Cycle is a team–based intervention and experiment platform to conduct large–scale and long–term, combination of investigations in real teams. This dissertation conducts experiments in real teams for measuring the effectivenesses of the information sharing models with Team Performance Indicator (*Team Performance*, *Comfortable Level*, *Team-Efficacy*, and *Team-Cohesion*) on *TBC-Cycle*.

The best of our knowledge, this dissertation tackles first time to measure the impact of information sharing on the team behavior change to measure the effectiveness of team–level behavior change.

1.4 The Thesis Statement

Consequently, as a first-time experiment, using *Sapplication Platform*, we evaluated and analyzed these models in order to "investigate the effects of different types of lifelog sharing models" through two extensive user study conducted with a baseball team (64 participants) for enhancing exercise (i.e., sit-up training), and a rugby team (21 participants) for empowering self-report activity over a period of three weeks as a first time experiment.

As a result of the studies, *Team Performance* showed that the effectiveness of information sharing is closely related to the team's goal and a type of information. Further, use of the team–based "competition" model was the most effective for teams in a competitive situation, such as sports teams, among the proposed models. In addition, the result of *Team–Cohesion* and *Team Efficacy*, as well known theory which has a causal relationship between the value and group performance, also shows that the team–based "competition" model is enhanced the *Team–Cohesion* and *Team Efficacy*.

The result suggest that, to share data which is related their team's goal using team–

based competitive information sharing (i.e., *iCL+eCP*) is the most effective for empowering their performance in the competitive sports teams in the university. Moreover, it is also indicate that the methodology of Team–Level Behavior Change research and Sapplication Platform have potentials to apply various types of team and collected data. Conducting the large scale and long–term is our future work using the Sapplication Platform and TBC–Cycle.

1.5 Contributions

This dissertation has the following contributions:

- As an attractive new interdisciplinary research, *team-level behavior change research*, using information sharing among team members in Ubicomp environment, has created in this dissertation.
- To enhancing team-level behavior change, we established *TBC-Cycle* to utilize buried data and proposed six-types of information sharing models (*IND, iCL, iCP, iCLCP, iCL+eCP, iCLCP+eCP*), that can be used as team-level interventions on the cycle, based on Competition and Collaboration techniques.
- In addition, through team-level intervention studies using the proposed information sharing models in the real teams are revealed that competition between teams (*iCL+eCP*) promotes team behavior change in the sports team that performs targeted competitive team sports.
- For end users, we implemented *Sapplication Platform*, which can easily conduct an evidence-based team-level intervention research using the proposed six types of information sharing models and *TBC-Cycle*.

1.6 Dissertation Road-map

Figure 1.1 illustrates the road-map of this dissertation. This dissertation establishes the above thesis through the following steps:

Chapter 2 presents the background of team–level behavior change research from a view point of computer science, behavior science (e.g., TTM and Self-efficacy), and social psychology. Chapter 3 describes related works of **Team–Level Behavior Change** researches using information technologies. Chapter 4 clarifies the research question of **Team–Level Behavior Change**, and proposes Team–Level Behavior Change Cycle which is included six types of information sharing models. Chapter 5 presents a system design and implementation of *Sapplication Platform* based on Team–Level Behavior Change Cycle, which is for fulfilling large–scale, long–term, and combinational investigations in real teams. Chapter 6 describes a first study for measuring effects of information sharing models in a baseball team and a research group. Chapter 7 describes, as a second study, a self–report study. Finally, Chapter 8 concludes this dissertation.

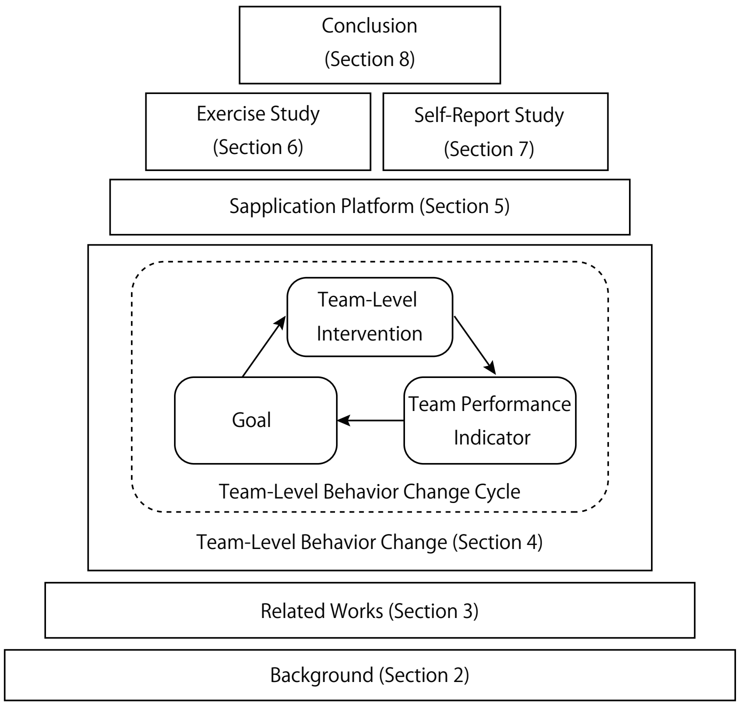

Figure 1.1: Dissertation Road-map

Chapter 2

Background

This chapter arranges a research background of team–level behavior change from viewpoints of Computer Science, Behavior Science, and Social Psychology. As shown in Figure 2.1, **team–level behavior research** is a research area where multiple research regions are related. At first, for describing a history of the research areas, Section 2.1 shows a history of ubiquitous computing in computer science. At second, in Section 2.2, efforts of human behavior change theories are expressed. Finally, Section 2.3 shows approaches and theories of human behavior in the society from perspective of the social science.

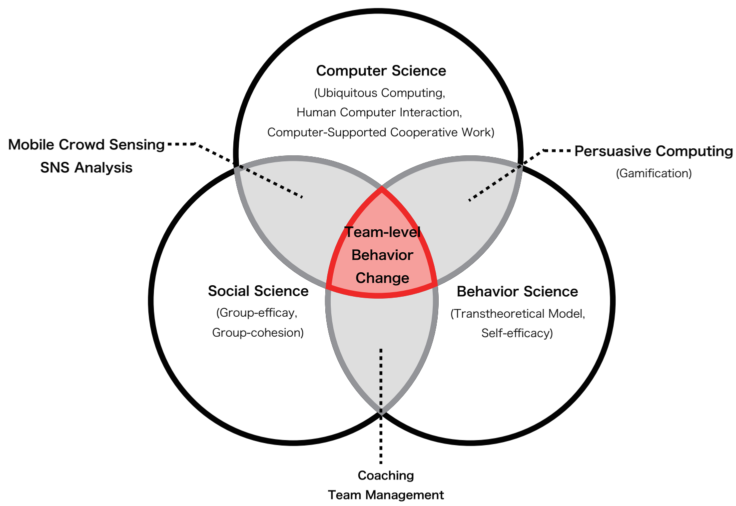

Figure 2.1: Research Area

2.1 Ubiquitous Computing

Around 1988, Mark Weiser advocated "Ubiquitous Computing" [13] which is a concept in computer science research; in the environment, various types of computing devices and systems support human activities everywhere and every time calmly. Moreover, he predicted the major trends in computing will be changed from mainframe (many people use one computer) to Ubiquitous Computing (one person has and uses many computers) around 1998 as shown in Figure 2.2.

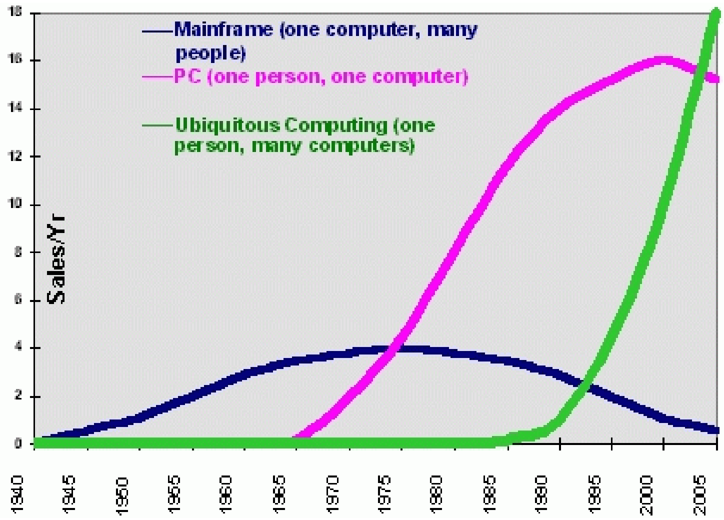

Figure 2.2: "The Major Trends in Computing" (Source [14])

Mobile and Wearable Computing (Section 2.1.1), Internet of Things (IoT) (Section 2.1.2), Life–logging (Section 2.1.3), and Big Data (Section 2.1.4) are novel paradigms in the Ubicomp Era. Moore's law is argued by Gordon E. Moore in 1965. The law defined "The number of transistors on the integrated circit doubles every 24 months." Nowadays, the processor performance is improved along with the law. In addition, a size of storage and network speed also improve exponentially. Based on the evaluated Information and Communications Technology (ICT), our life–style is dramatically changed from the beginning of computer science like a mainframe computing.

2.1.1 Mobile and Wearable Computer

Currently, smartphones support our daily life by using their rich computing resource on the device. The devices allow us to access digital information (e.g., e-mailing, phone calling, and web-browsing) anywhere and anytime. As shown in Figure 2.3, mobile devices are spread in Japan; 94.8% of people are using mobile phone or PHS. 62.6% of people are using smartphones, and the percentage is increasing rapidly. Moreover, over 90% of 20–39 age people use smartphones [15].

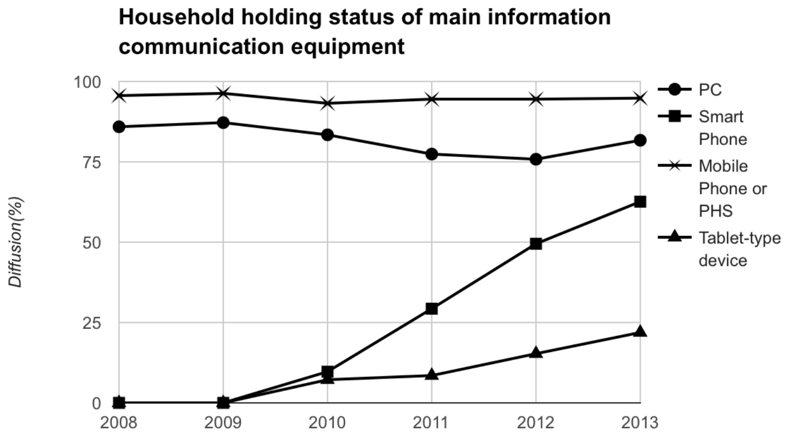

Figure 2.3: Spread of Mobile Phone [16]

Table 2.1 shows specifications of iPhone 7 as an example of a smartphone. The latest smartphones (e.g., iPhone[1] and Android[2], Windows Phone[3]) have variety of hardware components for sensing, storing, processing, and communicating modules on the device. The implemented modules enable to collect and share their daily activities on/-between the devices. For example, smartphoens have motion–(e.g., accelerometer and gyroscope, magnetic-field), location–(e.g, Global Positioning System, and compasses, air-pressure), environmental–(e.g., temperature, and ambient noise, camera) sensors.

Generally, on the device, a user install "Apps" for extending its function from each App market of each platform (i.e., an iOS device has AppStore, and Android OS has Play Store). Figure 2.4 shows a sample screenshot of AppStore. iOS users can download any Apps from the store. The market has a variety of Apps such as Games, Education, Photo&Video, Shopping, and Sports. Moreover, the market size (i.e., total download Apps) is estimated that the market will be expanded double from 2012 (total 26.6 billion Apps) to 2018 (total 56 billion Apps) [17].

Wearable devices' market (e.g., glasses, wrist, watch, and others) is also estimated

[1] `http://www.apple.com/iphone/`
[2] `https://www.android.com/`
[3] `https://www.microsoft.com/en-us/windows/view-all?col=phones`

Table 2.1: Specification of iPhone 7

Type	Specification
Weight	138g
CPU	A10 Fusion chip with 64-bit architecture (Quad-core 2.34 GHz) (ARMv8-A)
RAM	2GB
Display	4.7inch
Storage	256 GB
Network Interface	LTE
	Wifi (802.11 a/b/g/n/ac) Bluetooth (v4.2, A2DP, LE)
Sensors	Camera with 8 Mega Pixels and 4K video Microphone GPS Accelerometer Gyroscope Proximity Sensor Compass Barometer

that the market will be expected as shown Figure 2.5 and 2.6. Wearable devices (e.g., Apple Watch[4], Android Wear[5], Fitbit[6], Jawbone Up[7], MicrosoftBand[8], E4 wristband[9] series) allows to collecting a variety of human activity data in their daily life. For instance, Microsoft Band 2 has GPS, accelerometer, gyroscope, humidity, altimeter, galvanic skin response (GSR), heart-rate, RR interval (RRI), ultraviolet (UV) sensors. By using the sensors, the device can collect daily activities (e.g., running, walking, biking), quality of sleep, and stress-levels. In a ubiquitous computing field, SenseCam [19] is a wearable camera that captures daily record electronically. The camera records still images automatically, and simultaneously collects row–sensor data which is from built–in electronic sensors. In addition, Kim et al. [6] analyzed an organizational behavior using sociometric badges which have multiple sensors (e.g., microphone, accelerometer, and Bluetooth) and processing, storage modules. In a sport field, instead of optics motion captures which are expensive and huge, coaches are using wearable sensors for

[4] http://www.apple.com/watch/
[5] https://www.android.com/wear/
[6] https://www.fitbit.com
[7] https://jawbone.com/up
[8] https://www.microsoft.com/microsoft-band/en-us
[9] https://www.empatica.com/

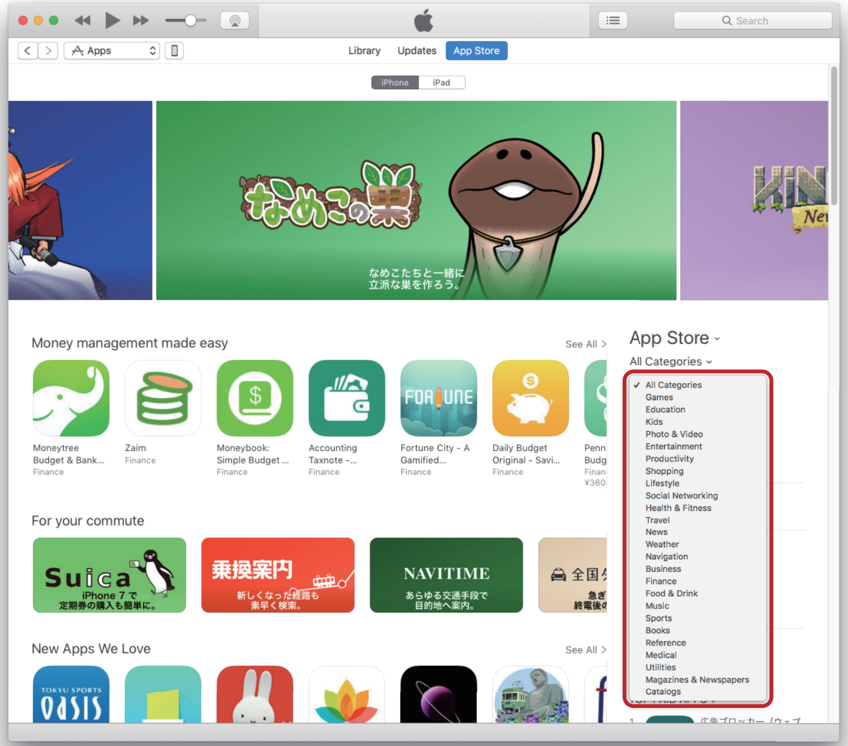

Figure 2.4: Screenshot of AppStore on iTunes

measuring their performance and collecting their daily practices. ZEPP[10] is a swing analysis tool which can use for swing sports (e.g., baseball, golf, and tennis.) The sensor analyses swing speed and orbit with only the sensor and a smartphone. Moreover, in the rugby, soccer, and american football, they are collecting players' positions and running speed, running distance by using wearable GPS sensors[11 12]. J!NS MEME[13], a glass type wearable device detects running form by 6-axis (3-axis accelerometer and 3-axis gyroscope) motion sensor data, and reviews runner's form, speed, and stride.

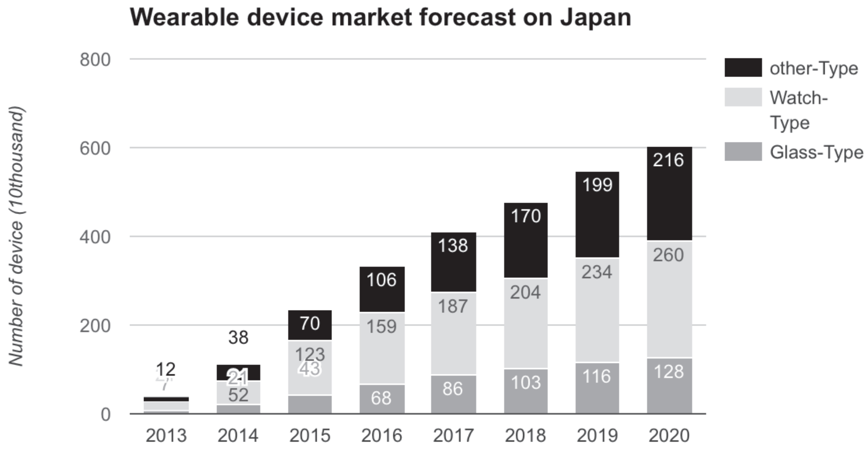

Figure 2.5: Spread of Wearable Devices in Japan [18]

2.1.2 Internet of Things

Internet of Things (IoT) is yet another trend for sensing technologies in the Ubicomp era. Figure 2.7 shows a forecast of a number of connected devices to the Internet from 2009 to 2020. The forecast shows that connected things will be expanded to 260 hundred million devices in 2020 from 9 hundred million devices in 2006. Besides, the same forecast expressed that the number of smartphone and tablet, PC will be increased to 73 hundred million devices from 16 million devices. The number of Internet of Things is estimated that its will be larger than the mobile devices.

As an example of connected things, i–POT [14] is an network connected electric pot for watching elderly people. The pot reports usage of the pot by the pot's owner(s) (i.e., elderly people) to a family who lives in a further place via the internet. The family can understand the elderly's life rhythm casually via the Internet. Smart City Project is an application of IoT. SmartSantander [15] project deployed 20,000 sensors on Santander city, and collect data (e.g., parking status, environmental data, traffic quantity, location of buses/taxis) from the deployed sensors. Moreover, the data is

[10] http://www.zepp.com/ja-jp/
[11] http://gpsports.com
[12] http://www.catapultsports.com/jp/
[13] https://jins-meme.com/ja/run/
[14] i–POT, ZOJIRUSHI, http://www.mimamori.net/
[15] http://www.smartsantander.eu/

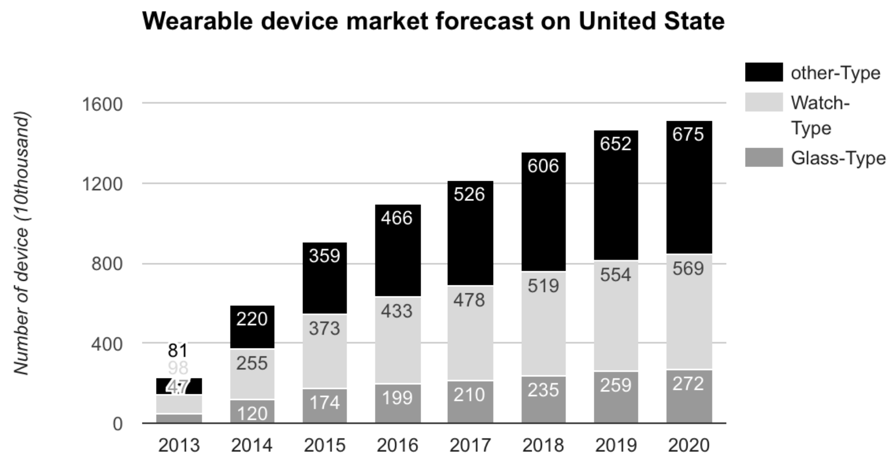

Figure 2.6: Spread of Wearable Devices in US [18]

provided for application developers, researchers, service providers, and general citizens for developing new services and/or predicting city events.

2.1.3 Life–logging Technologies

The spread of smart devices (i.e., mobile/wearable devices and IoT) allows collecting not only object and city context from the sensors but also human's daily activity easily. The stored human related data is called Personal data or Lifelog data [21]. A report by The World Economic Forum ranks the data as follows:

> *"Personal data is the new oil of the Internet and the new currency of the digital world [22]"*

The data includes Searches History, Calendar Events, Location, Purchases History, Interests, Social Graph, Contents of Microblog or Social Network Services (SNS), and Medical History. A report from the Ministry of Internal Affairs and Communications [21] related that the data has a huge potential to generate new industries, improving convenience of services, and realization of a safe and secure society.

For example, daily activity loggers on mobile wearable devices such as Moves[16], Human[17], or Arugs[18] record our daily activities (location, steps, transfer) throughout a

[16] `https://moves-app.com/`
[17] `http://human.co/`
[18] `https://www.azumio.com/s/argus/index.html`

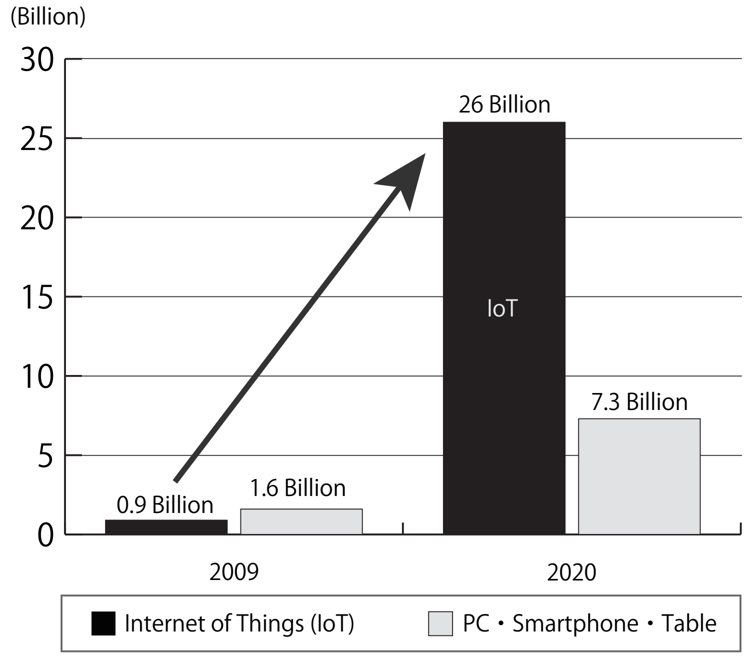

Figure 2.7: Improvement of Internet of Things: Forecast of a number of connected devices to the Internet (Source: [20])

day automatically. Furthermore, the technologies are used as an exercise (e.g., running, sit-ups, biking) logger such as RunKeeper[19], and Runtastic[20], Sit-Ups[21]; these applications collects distance and speed of running, In Ubiquitous Computing research field, StressSense [23] recognized stress level by using a microphone on off-the-shelf sensor-enabled mobile phones. Hemminki et al. [24] created accelerometer-based transportation mode detection system. The system can detect seven transportation modes such as stationary, walk, bus, train, metro, tram, and car using accelerometer features on a smartphone. Rooksby et al. [25] collected and visualized participants screen time (i.e., device usage time) on a mobile phone (iOS and Android) and personal computers (Mac and Windows) for increasing productivity and device use, and cutting down on use it.

[19] https://runkeeper.com
[20] https://www.runtastic.com/
[21] https://www.runtastic.com/en/apps/situps

2.1.4 Big Data

Due to the spread of the powerful and useful devices, IDC [26] which is a market research organization for mainly Information Technologies estimated that an amount of digital data in the world will be grown from 130 exabytes to 40,000 exabytes from 2005 to 2020 as shown in Figure 2.8. In 2008, Google has processed more than 20 Petabytes

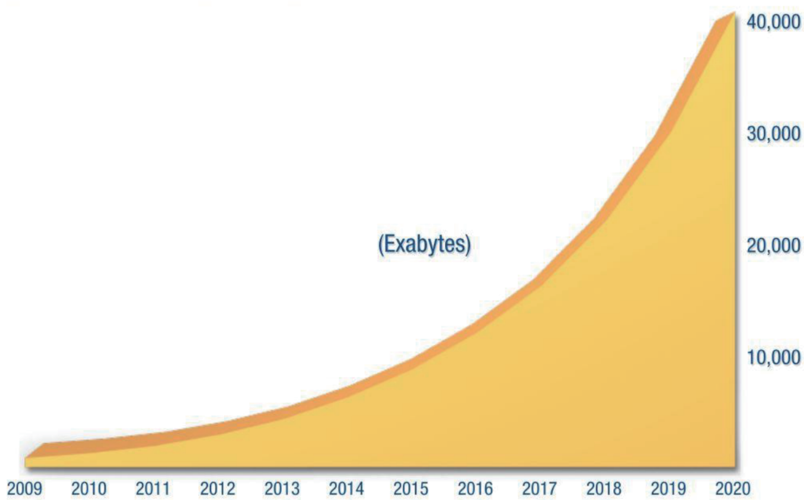

Figure 2.8: Predication of Increasing Amount of Data (Source IDC [26])

in a day [27]. In addition, Facebook [28] showed that a total amount of picture size is 1.5 Petabytes in their database. The different variety of huge stored data is called "Big Data" and the data influences a wide variety of fields such as recommender system on electronic commerces [29], social event detection analyzing micro–blog data [30, 31], and anomaly detection [32].

2.2 Behavior Science: Human Behavior Change

World Health Organization (WHO) reported [33] that the leading global risks for morality in the world are lifestyle related diseases such as high blood pressure (responsible for 13% of deaths globally), tobacco use (9%), high blood glucose (6%), physical inactivity (6%), and overweight and obesity (5%). Moreover, these diseases cause of raising the risk of chronic diseases such as heart diseases, diabetes, and cancers. Ways for preventing the risks is to take healthy lifestyles. However, in many cases, the ideal lifestyle will be not continued for a long term.

Behavior Therapy is a methodology for modifying a current behavior pattern to an ideal behavior pattern. The methodology is applied to various ideal activities such as no–smoking support, exercise promotion, and health–care. The effects of interventions for participants are evaluated by changes of target behavior (e.g., time, count, and amount), and theories from behavior science such as Self–Efficacy [34], and Transtheoretical model (TTM) [35].

Behavior change is defined as "changing the behavior pattern with which one was originally accustomed to a new one [35]." One simple example is a person changing his/her transportation behavior during his/her commute from "using escalators" to "using stairs" for his/her health. Prochaska proposed a human behavior change model called the TTM [35] that classifies the process of behavior change into the five stages shown in Figure 2.9. This model is broadly used to support various types of health activities [34], including quitting smoking [35]. Bandura [34] explained the importance of self-efficacy in the behavior change stage. An experience of achievement was found to be the most effective for improving self-efficacy.

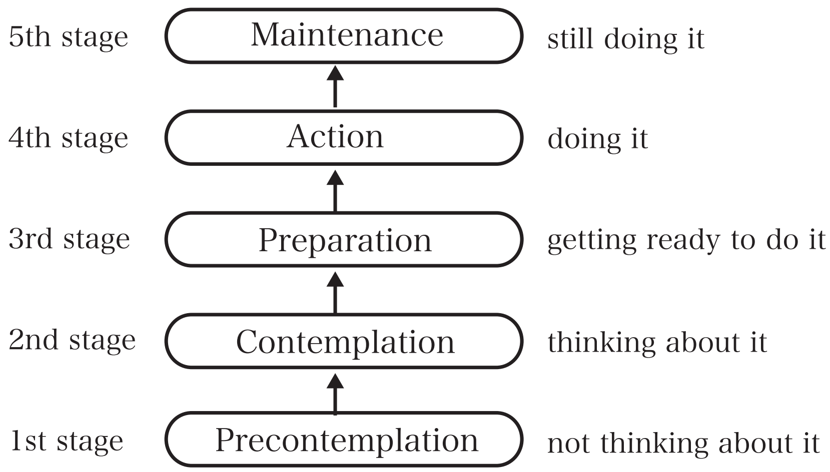

Figure 2.9: Stage Model of Behavior Change

2.3 Social Psychology

In the civilized society, most people live in organized groups such as a school, a company, a family, a neighborhood association, and a sports team for a long time to help each other. Aristotle who is a philosopher in the ancient Greek said about human in the nation as follows;

"The human is a political animal [36]."

In this sense, from B.C.E. to the present, human make groups and lives in the groups for supporting their activity. The human activity in the social is researched in the social science and psychology. In the research area, "Team Cohesion" [37, 38] and "Team Efficacy" [39] are a key theory in which both have a causal relationship between the value and performance (for achieving their goal) of sports teams. The theories are thought has a significant effect on team performance. For example, in 1990 Spink [40] investigated a relationship between team–cohesion and team–efficacy level on a volleyball team. As a result, an elite player showed a high team cohesion and efficacy, although the recreational team did not show the same phenomenon with the elite player.

The **Team Cohesion** theory is defined by Lewin [41]. A concept of the theory indicates "closeness of a group." For measuring the theory, Yukelson et al. [37] proposed a questionnaire based scale which has 22 items with four subscales in 1984, and Carron et al. [42] developed a similar scale for measuring the theory. In Japan, Ae [38] translated and recreated the Yukelson's questionnaires for Japanese. Table 2.2 shows the items of the recreated questionnaire which has 19 items with five subscales (i.e., *friendliness among members, teamwork, attraction, valuable role, and preparation to their goal*). Moreover, each item is answered using seven scales (1: Totally Different – 7: Totally Agree), and a high point means the group or the team have a high *team cohesion*. As a result of their evaluation, they showed that the statistics of the questionnaire is consistent with a concept of the theory.

Bandura [39] proposed **collective–efficacy** as well as **self–efficacy** in 1978. In the sports psychology researches, the concept of the theory is defined as "A belief about competence for their goal which sharing within team members." by Nagao at el. [43] The theory in other related researches is called "group efficacy [44]" and "team efficacy [45]." However, each name is used for same meaning with Bandura's definition. Therefore, we call the theory as **Team Efficacy** in this thesis. Previous researches suggest that team efficacy has a significant relationship between the theory and performance of teams. The group efficacy was measured in American Football [46], Rugby [47], and Basketball [48] teams, and previous researches suggested that enhancing the team efficacy promotes team performance. For measuring the team efficacy, Short et al. [49] developed and validated the Collective Efficacy Questionnaire for Sports (CEQS). In Japan, Nagao [50] developed Japanese Collective Efficacy Questionnaire for Sport (JCEQS) based on the CEQS, and validated JCEQS. As shown in Figure 2.10, JCEQS has 10 items, and each item is answered by 10 scales (1: Not completely confident — 5: Neither — 10: Very confident).

The Japanese Collective Efficacy Questionnaire for Sports: JCEQS

For each question, how much do you think the team you belong to in the **next game** will be **"able to do"?** Please circle the most applicable number from 0 to 10.

	I am not completely confident					Either					I am very confident
1. Our team can demonstrate our abilities.	0	1	2	3	4	5	6	7	8	9	10
2. Our team can overcome various obstacles that happen to the team.	0	1	2	3	4	5	6	7	8	9	10
3. Our team can do good plays more than other teams.	0	1	2	3	4	5	6	7	8	9	10
4. Our team can solve problems.	0	1	2	3	4	5	6	7	8	9	10
5. Our team can always be positive.	0	1	2	3	4	5	6	7	8	9	10
6. Our team can make good strategies.	0	1	2	3	4	5	6	7	8	9	10
7. Even if there is pressure, our team can playas usual.	0	1	2	3	4	5	6	7	8	9	10
8. Our team can play without spare effort.	0	1	2	3	4	5	6	7	8	9	10
9. Our team can good plays even if the environment is not best.	0	1	2	3	4	5	6	7	8	9	10
10. Our team can get enough communication always.	0	1	2	3	4	5	6	7	8	9	10

Figure 2.10: The Japanese Collective Efficacy Questionnaire for Sports: JCEQS (Source [50]) (Japanese version is attached on Appendix A)

In the addition, social psychology researches for the group behavior analytics investigate relationships between the value of survey (i.e., “Team Cohesion” and “Team Efficacy”) and the teams’ performance with static experiment; in their methodology, they collect participants’ conditions at the *beginning* and *end* of a study as well as free text survey and interviews. Finally, they observe events and analyze phenomena in the team.

2.4 Summary

This section described research backgrounds of team–level behavior changes research from viewpoints of Ubiquitous Computing (Section 2.1), Behavior Science (Section 2.2), and Social Psychology (Section 2.3).

- The spread of smartphones, wearable devices, and IoT technologies allows collecting various types activities in our daily life; besides, amount and kinds of collective data will be expanded rapidly in the Ubicomp Era (see Section 2.1).
- More than 90% of people whose ages are 20–40 has a smartphone in Japan. Therefore, nowadays, the foundation of mobile and wearable computing makes opportunities for accessing the Internet in anywhere and anytime. Moreover, it has huge potential to generate new market and change our life more conveniently.
- Behavior Therapy is a methodology for modifying a current behavior pattern to an ideal behavior pattern by interventions. The methodology is applied to various ideal activities such as no-smoking support, exercise promotion, and health-care. Besides, the research establishes a theory for the instance TTM (see section 2.2).
- In the current civilized society, most people live in organized groups for a long time to help each other. Moreover, social sociology has a long history to develop methodologies for measuring human activities in organized groups and generating theories (e.g., Team–Cohesion and Team–Efficacy) of human activity by observations (see Section 2.3).

Table 2.2: An Instrument of Measure Cohesiveness in Sport Team (Source: [38]) (Japanese version is attached on Appendix B)

Subscales	Question Number	Question
Friendliness among members	1.	I feel friendship with our team and I am satisfied with it.
	2.	There are lots of troubles within our team, and we can not get along with each other.
	3.	I think that team members in our team is intimate.
	4.	Even outside team activities, members are doing great with each other.
	5.	I think the relationship between the members is good.
	6.	Team members have strong colleague consciousness with each other.
	7.	I like human relations within our team.
Teamwork	8.	Communication between team members is few.
	9.	Even if we lost a game, our team is solidly gathered.
	10.	Our team demonstrates great teamwork in a game.
	11.	All members are aware of their role within the team.
Attraction	12.	I think that our team can be put together for winning a game.
	13.	Your contribution to your role and team is well recognized by the members.
Valuable role	14.	Your role and contribution to the team are well recognized by the coaching staff.
	15.	I feel that being a team member is very valuable.
Preparation to their goal	16.	I am very proud of being a member of the current team.
	17.	I think that current coaching method is good.
	18.	I am given enough information which is required for a game from coaches.
	19.	I think the information is fully understood and well-trained for a game.
Norm	20.	I think that skipping practice should not be allowed.
	21.	To rest a practice is unaboidable, and it should be allowed.

Chapter 3

Related Works

This chapter describes related works of **Team–Level Behavior Change** researches using information technologies. First, Section 3.1 shows related researches for promoting human behavior change using Information Technologies as intervention methods. Second, attempts of promoting group– and community– level behavior change are explained in Second 3.2. Finally, Section 3.3 express crowd behavior sensing technologies using the spread mobile devices.

3.1 Individual–level Intervention

In the Ubiquitous computing and Human Computer Interaction (HCI), Behavior Science, and Social Science, there is rich histories behavior change. As shown in Figure 3.2 which is a report by Hekler [51], in the last 10 years, behavior change related researches are increased dramatically in HCI research community. Most of these researches focus on *individual–level behaviors change* such as diet [52, 53] and exercise [54, 55, 56], sustainable water usage [7], time management [57, 25]. Moreover, these researches used Persuasive Computing [58] and/or Gamification [59, 60] technologies for enhancing, promoting, and modifying the activities. Figure 3.1 shows an overview of system process to enhancing human behavior using the technologies.

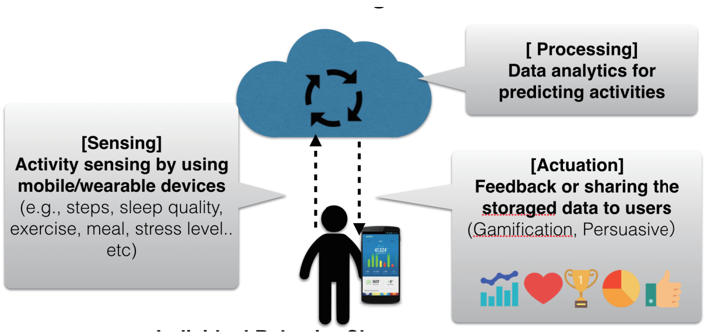

Figure 3.1: Intervention Overview of Individual-level Behavior Change Research

The concept of persuasive computing [58] for enhancing human behavior changes with the use of information technology has been extensively studied and the research outputs have been utilized in a wide variety of real-world products and services. "Gamification" [61, 59, 60] is developed in persuasive computing researches and known to be effective for promoting human behavior change [54, 57, 56].

This framework comprises of several techniques, such as "competition," "collaboration," "score," "ranking," "value sharing," "award" and "level up." Health promotion applications and web services with wearable devices, for example, Fitbit products[1], Nike+ Fuelband[2], and Jawbone UP[3], have already introduced those techniques such as "score," "award," "value sharing" and "ranking" into their functionalities.

[1]Fitbit One (`http://www.fitbit.com/jp/one`)
[2]NIKE+ FuelBand SE (`http://www.nike.com/jp/ja_jp/c/nikeplus-fuelband`)
[3]JAWBONE UP (`https://jawbone.com/up`)

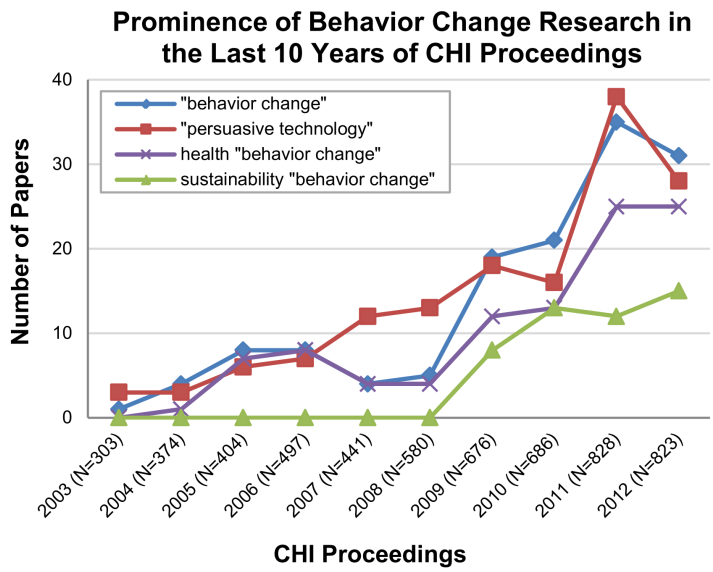

Figure 3.2: Prominence of Behavior Change Research in the Last 10 Years of CHI Proceedings (Source [51])

3.2 Group–level Intervention

In recent years, the research of individual behavior change is moving to group– or community–level intervention as shown in Figure 3.3.

With the spread of mobile/wearable devices, numerous research has been conducted exploring behavior change in groups such as friends [9, 62], school classmates [1], and laboratory members [8, 5]. Within these systems, gamification techniques are used to change the behavior of a "community." However, the studies have not considered combinations of intervention (i.e., Gamification, Persuasive Computing, and Information Sharing) techniques.

For example, Consolvo et al. [9] examined the influence of physical activity by step–count sharing using simple competition techniques in a female community. The result of their study suggested that using a "simple competition technique" is effective for behavior change in a community of female friends. *The American Horsepower Challenge* (AHPC) [1], a pedometer–based pervasive health game for the middle–school students ' community in the United States, was also utilized in a study. The aim of that study was to increase daily physical activity (i.e., steps) to prevent obesity. The AHPC was used as a competition technique for schools. The study showed that the participants' physical activity levels increased during the challenge. Moreover, Aharony et al. [12] tackled data–driven social science with high–quality multi–dimensional datasets, and executed structured experimental interventions in the real world for understanding and measuring social mechanisms, called *Social fMRI*. In their research, their collects over 25 different types of data (e.g., GPS signal and proximity to nearby Bluetooth devices, WiFi access point ID, accelerometer, call histories, SMS logs etc) from smartphones. In addition to the data collection and social interaction analysis, in their research, they tried intervention for enhancing participants human activity level from viewpoints of social support effects. Among research laboratory members, Fish'n'Steps [8] investigated the impact on their behavior (i.e., daily steps) change and social influences by using gamification system which is shared their steps as a transformation of virtual pets' shapes. In their research, they created a virtual pet system for visualizing participants steps abstractly; The pet is evolved by participants' number of steps. Additionally, they compared the system between *individual–* and *group–condition*; In the group condition, participants can check the other members progress and team-ranking (i.e. "healthiest" ranking.) As a result, they described that the effects of the intervention for behavior change depend on the current physical activity level of a participant and their satisfaction with it, their motivation to change it. However, they only observed a group behavior using an intervention method. In the other word, they had not compared differences between combinations of intervention methods and groups yet.

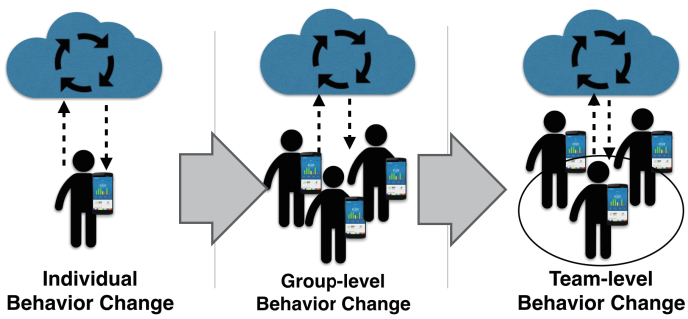

Figure 3.3: The transition from Individual-level to Group– and Team–Level Behavior Change Research

3.3 Social Behavior Analytics with Mobile Devices

Human-subject researches in Ubicomp and HCI collect participants' activities by using the spread mobile devices and analyze/predict various human activities [12, 63, 64, 6] individually or collectively. For example, Rachuri et al. [65] developed a mobile sensing platform for social psychology studies based on mobile phone, called *Emotion Sensor*. Their developed system can detect individual emotions, verbal and proximity interactions between social group members from the sensors (e.g., Microphone and GPS, Accelerometer) on off-the-shelf smartphones. Similarly, StudentLife [63] measured hidden stress and strain of student life from data from smartphones. Especially, they focused on detecting a day–to–day and week–by–week impact of workload on stress, sleep, activity, mood, sociability, mental well–being and academic performance. In the SmartGPA [64], by using the data–set of StudentLife, Wang et al., predicted academic performance of participants.

Mobile crowd sensing (MCS) tools, application, and platform are developed for supporting those researches [66, 67, 68, 69, 70, 71]. Google Form [66] and SurveyMonkey [67] are powerful web–based survey services (i.e., Experience Sampling Methods (ESM)) which is used tons of human subject researches. However, the platforms do not support to send surveys any time. PACO (The Personal Analytics Companion) [68] is a mobile application for ESM. On the application, researchers can make scheduled and event–based ESMs. Nevertheless, the platform can not collect hardware sensor data (e.g., accelerometer, and ambient noise, location) flexibly. Denzile et al. developed AWARE Framework [69] which can collect hardware (e.g., accelerometer, GPS, and air-pressure)– and software (e.g., battery, screen, and network)–, human-based–(e.g., ESM, keyboard, and microphone) data using mobile client. In the addition, AWARE allows to handle (i.e., sending ESM remotely and setting sensing frequency, turn–on/off sensors) their large–scale human subject study easily and remotely, flexibly through a web dashboard.

According to a market research[4], Android has 71.94% market share, and iOS has 18.89%; in the other word, both two major OS are covering over 90% of mobile OS in the world as shown in Figure 3.4. Interestingly, in Japan and some countries (e.g., Canada and United State, United Kingdom), iOS's marker share is bigger or almost same than Android. For example in Japan, iOS has 72.45% to Andorid's 26.43% in December 2016 as shown in Figure 3.5.

[4] `http://gs.statcounter.com/`

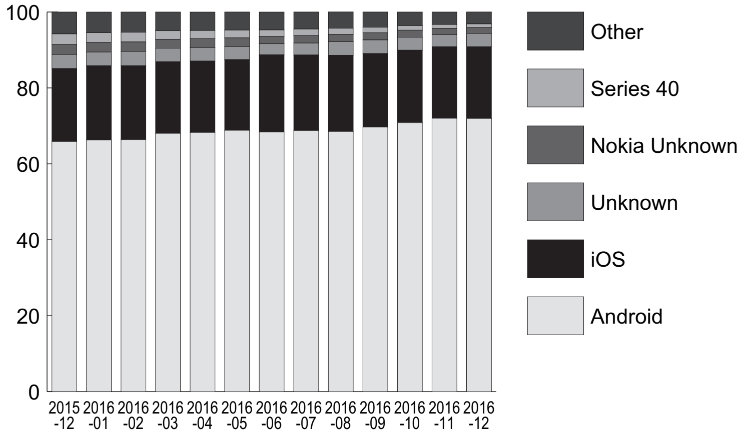

Figure 3.4: Worldwide Market Share of Mobile Operating Systems

Generally, application support on cross-platform (i.e., working on iOS and Android, Windows phone) is high development and management cost for MCS researchers because they have to learn programming languages such as Java and Objective-C, Swift. Haoyi et al developed Sensus [70] which is also an MCS Platform. The platform is built on top of the Xamarin platform [5] (i.e., one of the cross–platform development platform) then programmers can expand the mobile client and use native libraries on each operating system using only C#. Moreover, on the Sensus, researchers make a sensing protocol and ESM contents schedules on Sensus mobile client and distribute it via email.

Experience Sampling Methods (ESM) and Ecological Momentary Assessment (EMA) (i.e., survey) are research methodologies for collecting examinees' momentary assessment [72, 73, 74, 75]. Participants who are enrolled a study record temporal thinking and their feeling in the moment to memo or digital devices. Generally, the techniques are used for sampling methods for human-related data (e.g., stress-level, social-pressure, sleep quality.) For example, in StudentLife [63], they are recording participants' states (e.g., stress, mood) using well-known mental scale based EMA (e.g., PHQ-9, perceived stress, flourishing, and loneliness scales) during their study as an evidence data on their Android Application. Moreover, the latest ESM technologies on mobile device support not only periodical asking (i.e., sending a survey periodically) but also context-based (i.e., a sending a survey when a phone call is ended) and ran-

[5] `https://www.xamarin.com/`

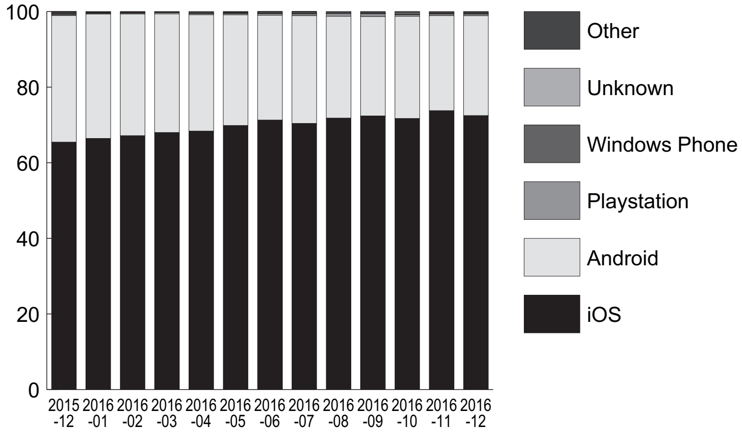

Figure 3.5: Market Share of Mobile Operating Systems

domize (i.e., sending a survey at randomly shifted time from a certain time) asking. However, their researches did not tackle group– or team–level behavior change.

3.4 Summary

In this section, we introduced the history of human behavior change research in Ubiquitous computing and HCI research community.

- The spread of smartphones, wearable devices, and sensor technology allows collecting various types activities in our daily life; besides, amount and kinds of collective data will be expanded suddenly.
- By using spread and high–performed smartphone, Ubiquitous Computing and HCI researches tackled evidence–based social activity sensing and analyzing without intervention which called MCS. At once, they developed useful tools and platform for MCS researches.
- In the same way, using mobile/wearable devices, the researchers investigated effects of intervention techniques (i.e., Persuasive and Gamification) for an individual- and group-level behavior change.
- However, they only observed a group behavior using an intervention method. In the other word, they had not compared differences between combinations of intervention methods and groups yet.

Chapter 4

Team-Level Behavior Change

This chapter shows the importance of team–level behavior change research, and an approach to solve the research question.

First of all, our target team and goal are defined in Section 4.1. Based on the definition, Section 4.2 expresses a research question of team–level behavior change from relationships between related works. In Section 4.3, we propose Team–level Behavior Change Cycle (*TBC–Cycle*) which is a concept for enhancing teal–level behavior change using information sharing in a team, as a solution for solving the question. The cycle consist of three principal elements: (1) the goal of a team, (2) intervention methods, and (3) team performance indicator, and also, the role of each element in *TBC–Cycle* is expressed in Section 4.3.1, 4.3.2, and 4.3.3 respectively. Finally, Section 4.4 illustrates use–cases of *TBC-Cycle*.

4.1 Definition of Team

This section defines a target group (i.e., *team*) from a classification of groups (i.e., *circle, community, organization,* and *team*) as shown in Figure 4.1, and classifies the goals in the target group into two types (i.e., final–goal and sub–goal).

In the social psychology, a "Group" is defined a social group which is constructed from multiple people, and also, a group has the following characteristics severally. The group exists throughout a period of time, and the group members share their common goals and can help mutually. Goals in a team can be classified broadly into two types: "final–goal" and "**sub goal for achieving the final goal (sub–goal)**." A final–goal is a big team goal which will be achieved by long–term effort of team members. *"To win a championship"* is an example of a final–goal. However, the achievement of the goal is uncontrolable because the goal is influenced by external factors such as opponents, weather condition, and body physical/mental condition. The **sub–goal** is a measurable and shorter-term goal to achieve the final–goal. *"conduct sit–up 100 times every day," "response a questionnaire within three hours."* and *"take a sleep during 7 hours"* are examples of the sub–goal.

Figure 4.1 classifies the groups by *community, circle, team,* and *organization*; the vertical axis indicates the concreteness of their shared final-goal, whereas the horizontal axis indicates the scales of group. From the categorized groups, this dissertation focuses on "Team" as a target group. In Oxford Dictionaries [76], a team was defined that *"a group of players forming one side in a competitive game or sport."* Based on the definition, a team is defined that **a collection of people who share an obvious final–goal and who work together to achieve the final–goal** in this dissertation. In this sense, a sports team, a working team in a company, a project team in a research laboratory are teams.

Conversely, a group of people with "a shared final–goal is ambiguous (e.g., To live a healthy life)" or with "NO contribution to achieve their goal" is a circle. For example, existing researches focus on communities such as classrooms [1] and a community of friends [9], which are both different target team defined in this dissertation. Furthermore, group members whose have a common final–goal without acquainted with all members, is an "Organization" such as company and school. Moreover, "Community" shares a final–goal weakly between members in addition to acquainted with all members (e.g., a local resident and a group on Social Networking Services like Facebook[1] and/or Google+[2]). Both the groups (i.e., Organization and Community) are also different from our studied team.

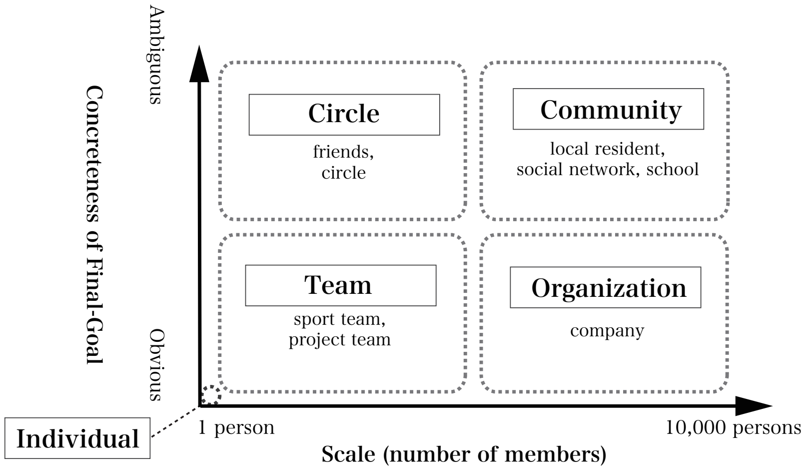

Figure 4.1: Classification of Groups

4.2 Motivation: Position of Team–level Behavior Change Research

Table 4.1 shows supported types of interventions and target group/person in the related works. In the types of intervention, the Individual type includes generating an award, level–up, and/or story techniques of gamification. Composite type means that it is a combined intervention method with competition and collaboration. In addition, check–mark (✓) means that the type of intervention is supported in the system or server.

Table 4.1 summarizes existing studies and products on *individual* [52, 54, 56, 7, 57, 25], *community* [77, 78], *circle* [79, 9, 1], and *organization* [12, 8, 5]–level based behavior change. For example, community–level behavior change, EverySpo! [77] is a number of steps sharing service in instant groups; if a team achieves a mission which is from operating company, they can obtain a real coupon. Moreover, the participated teams can compare their total steps among other teams for promoting motivation community–level. In addition, Nike+ Run Club app [78] provides social ranking about total running distance during a week/month/year to enhance users' motivation. As an

[1]Facebook (`https://www.facebook.com/`)
[2]Google+ (`https://plus.google.com/`

example of circle–level behavior change, Runtastic [79] provides a ranking function among selected friends for empowering their running motivation. In addition to the services, as an example of HCI research approach, Houston [9] examined effects of difference between competitive– and individual– intervention in a group which is composed of female friends. However, the research examined only circle type group and compared effectivenesses between competitive and individual intervention. Similarly, the organization–level researches [12, 8, 5] investigate effectivenesses of group–level intervention (i.e., information sharing in a group) in each organization. However, the participants include non–team members in their experiments. Therefore, it is not clear if such techniques for individual human behavior work effectively when they are applied to behavior change of *teams*.

Table 4.1: Position of Team–level Behavior Change Research among Existing Behavior Change Researches and Services

Research	Target	Types of intervention			
		Individual	Competition	Collaboration	Composite
Diet [52]	Individual	✓			
Ubifit [54]	Individual	✓			
Glanceable Feedback [56]	Individual	✓			
Water Usage [7]	Individual	✓			
Application Usage [57]	Individual	✓			
Screen Time [25]	Individual	✓			
EverySpo! [77]	Community	✓	✓	✓	✓
Nike+ Run Club app [78]	Community	✓	✓		
Runtastic [79]	Circle	✓	✓		
Houston [9]	Circle	✓	✓		
AHPC [1]	Circle	✓	✓		✓
Social fMRI [12]	Organization	✓	✓		
Fish'n'Steps [8]	Organization	✓	✓	✓	
Efstratiou et al. [5]	Organization	✓	✓		

Moreover, in teams, the content to be shared among the team members, use of behavior change promotion techniques including "collaboration" and "competition," as well as several fundamental properties of the team, such as the "goal of the team," are considered to have an influence on the team's behavior changes. Efstratiou et al. [5] constructed a web application that detects daily activities in their laboratory using small sensors and microphones, and used it to share activity information among laboratory members with the "competition" technique. Subsequently, they received exciting feedback such as, "*What was thought not to work by other member was unpleasant*." However, it is doubtful whether using the competition technique, such as simple ranking for encouraging behavior change, is effective for the whole team in terms of changing their behavior. Moreover, in their study, they only investigated the psychological influence of lifelog sharing on the team. Investigating the influence of lifelog sharing techniques is a major research challenge that is yet to be addressed.

4.3 Approach: TBC-Cycle

This section explains **TBC-Cycle** (Figure 4.3) as a research approach for enhancing team–level behavior change using information sharing in teams. A principal research approach to enhancing the individual–level behavior change has been studied in the Individual–level Behavior Change Cycle (IBC–Cycle) as shown in Figure 4.2. In the IBC–Cycle, first, a user decides a goal for behavior change. Second, the user or system selects intervention methods such as lifelog–data and feedback methods, for enhancing the selected goal. Finally, the user reviewing the effectiveness of interventions for next cycle to polish the intervention.

In this dissertation, we apply the cycle to team–level behavior change. The team has multiple members in a team, so that the elements of each step are different between TBC–Cycle and IBC–Cycle. Deciding a goal is described in Section 4.3.1 and Section 4.3.2 illustrates selecting parameters for team–level behavior change. Section 4.3.3 shows about Team Performance Indicator (TPI) for measuring the effectiveness of interventions.

4.3.1 Goals in Team

As described in Section 4.2, teams have various granularity goals (i.e., final– and sub–goal). In this dissertation, we focus on enhancing team–level sub–goal achievements. *"Conduct sit–up 100 times every day," "response a questionnaire within three hours."* and *"get 7 hours of sleep"* are examples of the sub–goal. This dissertation assumes that an accumulation of achieving sub–goal increase their possibility for achieving their final–goal.

As shown in Case–1 to –3 of Step–2 in Figure 4.3, direction of enhancement can

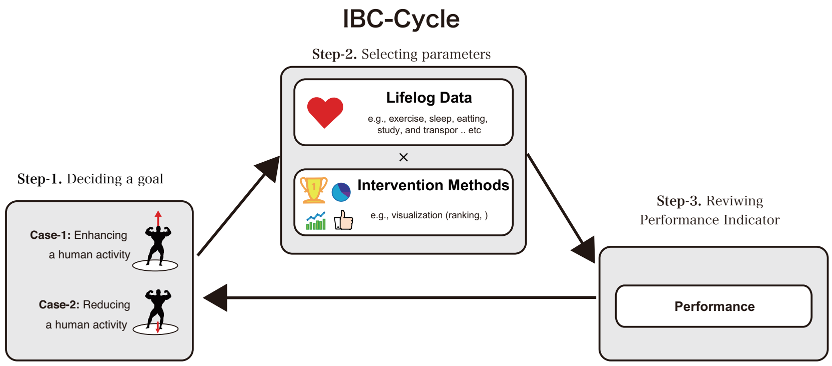

Figure 4.2: Structure of IBC-Cycle

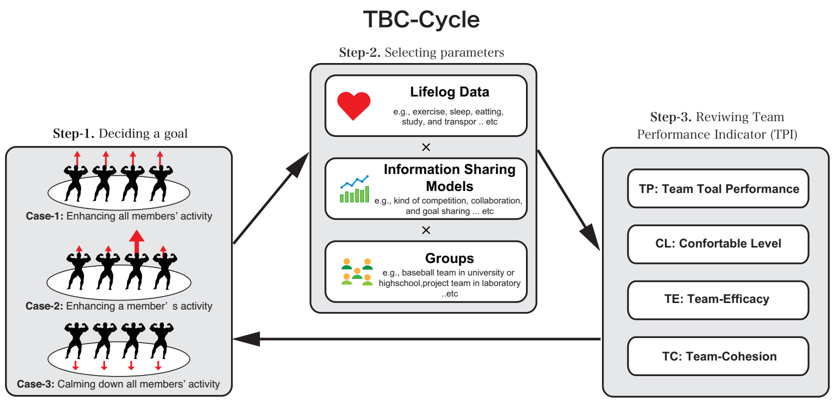

Figure 4.3: Structure of TBC-Cycle

be possible to think multiple ways: "Improving all members basic skill (Case–1)," "Enhancing a member's performance (Case–2)," and "Control the members' activities(Case–3)." From the cases, this dissertation addresses the case–1.

4.3.2 Information Sharing Models

In this section, we propose six lifelog sharing models for team behavior change promotion based on combinations of **collaboration** and **competition**.The competition and collaboration techniques are widely used by existing system and services as one of the important techniques for human behavior change. Similarly, it is assumed that the techniques influence the promotion of team behavior change.

Figure 4.4 shows the proposed lifelog sharing models. A black disk represents a team member while a dotted line oval represents a team. Two arrows facing each other signify competition between team members or teams while back-to-back arrows signify collaboration between teams. Further, Table 4.2 shows the elements of each lifelog sharing model. There are five types of elements: *individual activity*, *total activity of own team*, *individual member's activity of the same team*, *total activity of other teams*, and *individual member's activity of other teams*. In the table, "visible" signifies that the target of the lifelog sharing model has visible elements. For example, model *iCL* has elements of *own activity* and *total activity of own team*.

Competitive teams usually avoid making their own rivals stronger so that they may not like sharing sensitive information (like the current performance of each user) with the other teams. Therefore, to promote overall team performance, we assumed that of the proposed models (*iCL+eCP* and *iCLCP+eCP*) belong to the same team.

The definition of each of these models is given in detail below.

Table 4.2: Elements of each lifelog sharing model

Information Sharing Model	Own activity	Total activity of own team	Each member's activity of the same team	Total activity of other teams	Each member's activity of other teams
IND	visible	-	-	-	-
iCL	visible	visible	-	-	-
iCP	visible	-	visible	-	-
iCLCP	visible	visible	visible	-	-
iCL+eCP	visible	visible	-	visible	-
iCLCP+eCP	visible	visible	visible	visible	visible

Individual Model (*IND*)

The *IND* model is shown in Figure 4.5. The aim of this model is achievement of each member's own goal. Figure 4.6 is an example visualizing method by using the model. With this model, each user can access the lifelog of his/her own activities. No lifelog exchange occurs between members. Therefore, in *IND*, the pressure from other team members is lower than that of other models that include colleague lifelog sharing techniques such as collaboration and competition. Because *IND* has no promotional elements, it is assumed that the amount of activity is lower than other lifelog sharing models.

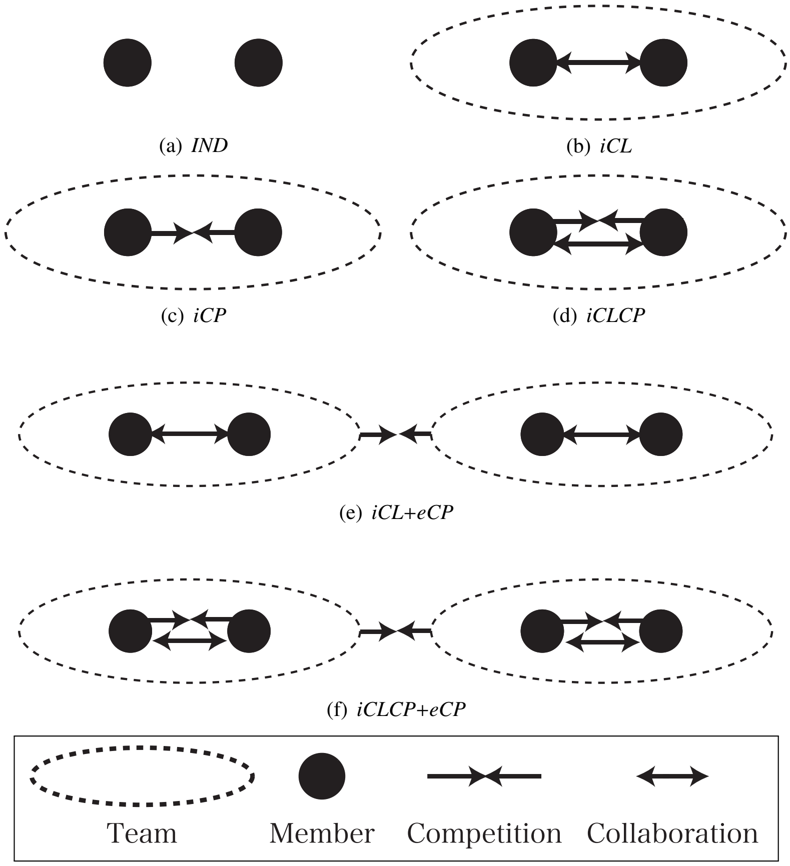

Figure 4.4: Information Sharing Models

Figure 4.5: *IND*: Concept of Individual Model

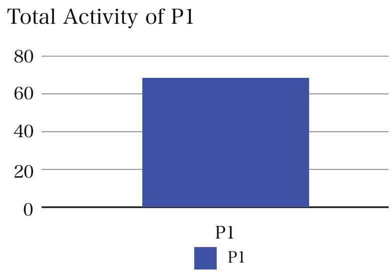

Figure 4.6: Example of *IND*

Internal Collaboration Model (*iCL*)

The *iCL* model is shown in Figure 4.7. The aim of this model is to encourage collaboration between team members, given by a common goal (the total amount of activity by the team). Figure 4.8 is an example visualizing method by using the model With this model, each team member can access the lifelog of his/her own activities, as well as the total (summated) amount of activity achieved by all team members. Knowing the total amount of activity encourages team members to achieve the team goal. This model does not provide team members' individual activity lifelog such as the daily activity. Therefore, the level of discomfort with lifelog sharing is lower than that with a model that uses simple competition techniques with team members. However, this model shares team members' activity information as total team activity, and so the pressure of lifelog sharing is greater than that of *IND*.

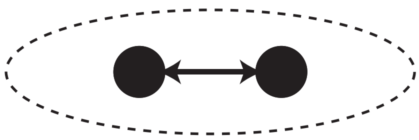

Figure 4.7: *iCL*: Concept of Internal Collaboration Model

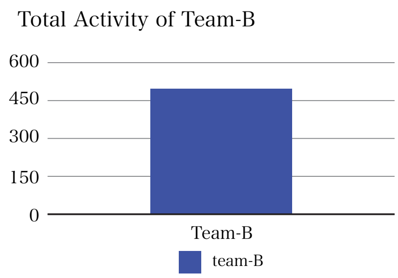

Figure 4.8: Example of *iCL*

Internal Competition Model (*iCP*)

The *iCP* model is shown in Figure 4.9. The aim of this model is to encourage competition among team members. Figure 4.10 is an example visualizing method using the model. With this model, each team member can access the lifelog on his/her own amount of activity, as well as those of other individual members of the same team. The total amount of activity achieved by all team members is not shared. The *iCP* model provides all team members' daily activities, and so this model promotes competition among members. Moreover, it is assumed that the amount of activity is greater than that of *iCL* as a result of the increased stimulus from sharing lifelogs. On the other hand, all members will know the least active member, which makes the discomfort from this model greater than that of *iCL*.

Internal Collaboration and Competition Model (*iCLCP*)

The *iCLCP* model is shown in Figure 4.11. This model is a combination of *iCL* and *iCP*. With this model, all members' individual amount of activity, as well as the total

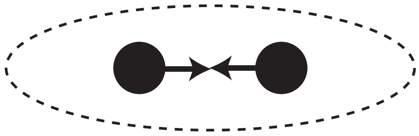

Figure 4.9: *iCP*: Concept of Internal Competition Model

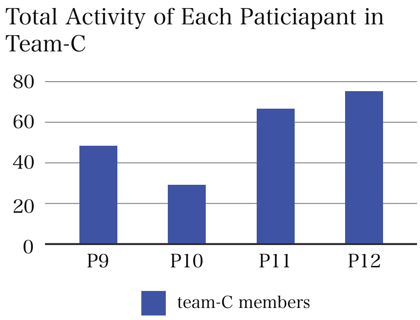

Figure 4.10: Example of *iCP*

amount of activity of the team, is shared among team members. Figure 4.12 is an example visualizing method by using the model Using two concepts from *iCL* and *iCP* at the same time, the amount of contribution by individual team members becomes more obvious towards the achievement of the team goal. Because the amount of pressure from other members is greater than the *iCL* and *iCP* models used in isolation, the amount of activity from each individual member should experience a boost. In addition, it is considered that the total amount of activity of the team will be increased.

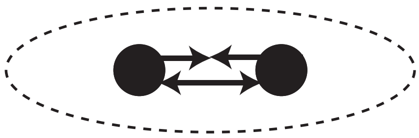

Figure 4.11: *iCLCP*: Internal Collaboration and Competition Model

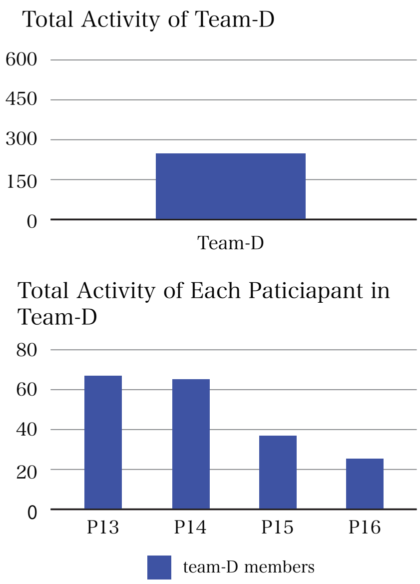

Figure 4.12: Example of *iCLCP*

Internal Collaboration and External Competition Model (*iCL+eCP*)

The *iCL+eCP* model is shown in Figure 4.13. This model is a combination of *iCL* and competition between multiple teams, which is called external competition. Figure 4.14 is an example visualizing method by using the model The aim of this model is to encourage competition among teams by visualizing each team's total activity. Each team member can access the lifelog of his/her own activity, the total amount of activity achieved by the team that he/she belongs to, and the total amount of activity achieved by competing teams. This model has a clear goal of *"Winning the opposing team"*: thus, team members try to achieve a better total team activity amount collaboratively to compete with other teams. Competition among members of the same team does not occur because this model does not share the activity of individual team members.

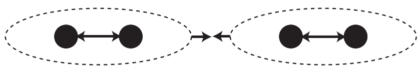

Figure 4.13: *iCL+eCP*: Internal Collaboration and External Competition Model

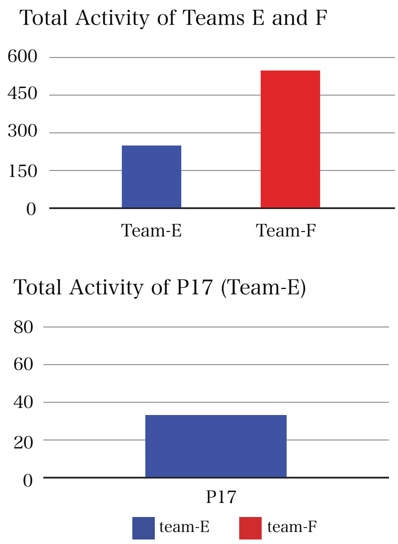

Figure 4.14: Example of *iCL+eCP*

Internal Collaboration, Competition and External Competition Model (*iCLCP+eCP*)

The *iCLCP+eCP* model is shown in Figure 4.15. This model is a combination of *iCLCP* and competition between multiple teams. Figure 4.16 is an example visualizing method by using the model The aim of this model is to encourage competition among team members, as well as competition among multiple teams, with collaboration between team members occurring simultaneously. With this model, each team member can access all types of information, such as information on his/her own activity, the activity of other individual team members, the total amount of activity achieved by the team he/she belongs to, and the total amount of activity achieved by competing teams. As with the *iCL+eCP* model, team members try to contribute to the total team activity collaboratively in a competitive situation with other teams. However, this model may also simultaneously lead to competition within the team because the activity of individual team members is shared. Because there are two types of competitions in this model, the amount of pressure on each member is greater than in the *iCL+eCP* model.

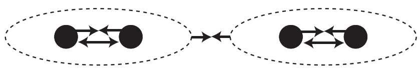

Figure 4.15: *iCLCP+eCP*: Internal Collaboration, Competition and External COmpetition Model

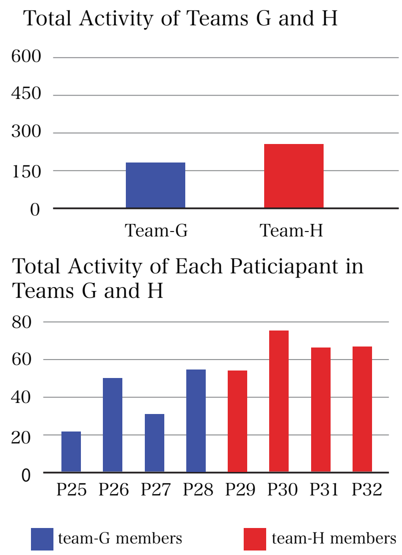

Figure 4.16: Example of *iCLCP+eCP*

4.3.3 TPI: Team Performance Indicator

We define **team-level behavior change** as “the increased amount of total score of a team with lifelog sharing compared to a team with no lifelog sharing.”

In this study, team-level behavior change comprises four elements:

- Team Performance : TP
- Comfort Level of Information Sharing : CL
- Team–Efficacy Level: TE
- Team–Cohesion Level: TC

TP: Team Performance

TP is calculated from **the total score of all team members,** as shown in formula (4.1), where $IP(i,t)$ denotes the individual performance (IP) of team member i at time t. Therefore, we say that the team-level behavior change is promoted, when the value of formula (4.2) is greater than 0:

$$TP(n,t) = \sum_{i=1}^{n} IP(i,t) \tag{4.1}$$

$$TP(n,new) - TP(n,old) \geq 0 \tag{4.2}$$

CL: Comfort Level of Information Sharing

CL is the **comfort level of team members with lifelog sharing**. It is calculated from a questionnaire regarding how comfortable a person feels using the system, as shown in formula (4.3).

Deterioration of CL leads to a bad influence from long–term usage. Maintenance of CL is therefore important. Participants answer the questions using a 5-point Likert scale (5-Strongly Agree, 4-Somewhat Agree, 3-Neutral, 2-Somewhat Disagree, 1-Strongly Disagree). The value of CL is $1 \leq CL \leq 5$. A larger value for CL signifies a higher level of satisfaction.

$$CL(n,t) = \sum_{i=1}^{n} (Q(i,t)) \tag{4.3}$$

$$(CL(n,new) - CL(n,old)) \geq 0 \tag{4.4}$$

TE:Team–Efficacy Level

"Team Efficacy" [39] is a well–known theory which has a causal relationship between the value and group performance. Bandura [39] proposed **collective–efficacy** as well as **self–efficacy** in 1978. In the sports psychology researches, the concept of the theory is defined "A belief about competence for their goal which sharing within team members." by Nagao at el. [43].

For measuring the *Team Efficacy*, this dissertation uses the Japanese Collective Efficacy Questionnaire for Sports (JCEQS) [50] which developed is based on Bandura's concept of group efficacy. For measuring the team efficacy, Short et al. [49] developed and validated the Collective Efficacy Questionnaire for Sports (CEQS). In Japan, Nagao [50] developed the Japanese Collective Efficacy Quastionnaire for Sport (JCEQS) based on the CEQS, and validated JCEQS. Table JCEQS has 10 items (TE–1 to –10), and each item is answered by 10 scales (1: Not completely confident — 5: Neither — 10: Very confident). Table 4.3 shows sample questions of the questionnaire. The "[—]" is modified by each team goal.

Table 4.3: Questionnaires about Team–Efficacy Level (Japanese version is attached as Appendix C)

#	Question
TE-1	Our team can demonstrate our abilities.
TE-2	Our team can overcome various obstacles that happen to the team.
TE-3	Our team can do [—] more than other teams.
TE-4	Our team can solve problems.
TE-5	Our team can always be positive.
TE-6	Our team can make good strategies.
TE-7	Even if there is pressure, our team can [—] as usual.
TE-8	Our team can [—] without spare effort.
TE-9	Our team can do [—] even if the environment is not best.
TE-10	Our team can get enough communication always.

TC:Team–Cohesion Level

"Team Cohesion" theory, which is defined by Lewin [41], also is a well–known theory for measuring a group performance. A concept of the theory indicates "closeness of a group." For measuring the theory, Yukelson et al. [37] proposed a questionnaire based scale which has 22 items with four subscales in 1984, and Carron et al. [42] developed a similar scale for measuring the theory. In Japan, Ae [38] translated and recreated the Yukelson's questionnaires for Japanese. Table 4.4 shows the items of the sample questionnaire based on the existing questionnaire based on Ae [38], which has 19 items with five subscales (i.e., *friendliness among members, teamwork, attraction, valuable role, and preparation to their goal*). Moreover, each item is answered using seven scales (1: Totally Different – 7: Tottaly Agree), and a high point means the group or team have a high *team cohesion*. The "[—]" is modified by each team goal.

Table 4.4: Questionnaires about Team–Cohesion Level (Japanese version is attached as Appendix D)

#	Question
TC-1	I feel friendship with our team and I am satisfied with it.
TC-2	There are lots of troubles within our team, and we can not get along with each other.
TC-3	I think that team members in our team is intimate.
TC-4	Even outside team activities, members are doing great with each other.
TC-5	I think the relationship between the members is good.
TC-6	Team members have strong colleague consciousness with each other.
TC-7	I like human relations within our team.
TC-8	Communication between team members is few.
TC-9	Even if the state of [—] is bad, the team is solidly gathered.
TC-10	My team demonstrates great teamwork for [—].
TC-11	All members are aware of their role within the team.
TC-12	I think that our team can be put together for [—].
TC-13	Your contribution to your role and team is well recognized by the members.
TC-14	Your role and contribution to the team are well recognized by the coaching staff.
TC-15	I feel that being a team member is very valuable.
TC-16	I am very proud of being a member of the current team.
TC-17	I think that the feedback method of [—] is good.
TC-18	I am given enough information which is required for [—] from the system.
TC-19	I think [—] is fully understood and well-trained for [—].

4.4 Use-cases of TBC Models

This section describes use cases of Team-level Behavior Change Models. As concrete examples, we illustrate two use case for TBC–Model as following: Section 4.4.1 shows use–case (1), and use–case (2) is described in Section 4.4.2.

- (1) Enhancing Team-level Exercise Behavior Change
- (2) Enhancing Team-level Self-report Activity

4.4.1 Use–case: Enhancing Team–Level Exercise Behavior Change

Figure 4.17 shows an overview of enhancing team–level self–report activity. A sports team (e.g., baseball team) in a university recommends to do sit-ups for promoting injury and enhancing physical performance, however, they are counting and seeing only their own data now. As a goal of team–level behavior change, a coach think to increase the number of sit-ups of all members. By using the TBC-Model, the *Sapplication Platform* shares their number of sit-ups (i.e., performance) to all of the members. Increasing the total number of sit-ups means that team–level behavior change is occurred.

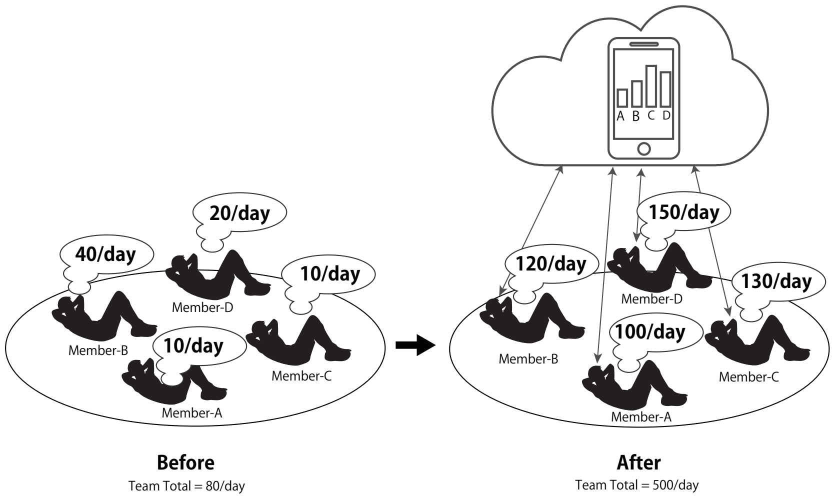

Figure 4.17: Overview of Exercise Behavior Change

4.4.2 Use–case: Enhancing Team–Level Self-report Activity

Figure 4.18 shows an overview of use–case of enhancing team–level self–report activity.

A sports team in a university is collecting players physical and mental data every morning for preventing serious injury and scheduling effective training program. Collecting the condition data quickly and immediately without human assistance that reduce a burden of data collection by coaches, and allow to change training and practice menu flexibly based on the players' condition data.

In the case of Figure 4.18, the average response time is +140 min from scheduled time (i.e., 8 AM). The total response time becomes shorter than before, means that a short time behavior change occurs.

4.5 Summary

The summary of the main contents in this section follows:

- A team is defined as a group that "sharing a common goal" and "contributing to achieving that goal" in Section 4.1.

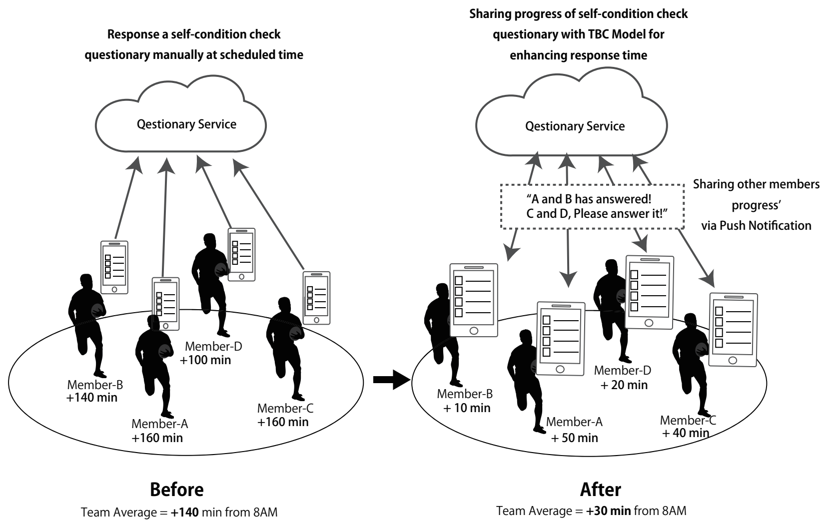

Figure 4.18: Overview of Self-report Activity Behavior Change

- *TBC-Cycle* is a research approach for enhancing team-level behavior change using information sharing in a team, and also the cycle is composed of three elements: *Information Sharing Model* (i.e., lifelog data, number of members, and six–types of data sharing methods which is based on competition and collaboration method (*IND, iCL, iCP, iCLCP, iCL+eCP, and iCLCP+eCP*)), four evaluation elements (i.e., *Team Total Performance* and *Comfortable Level*, *Team–Efficacy*, *Team–Cohesion*), and Goals (i.e., Sub Goal).

- Goals in a team can be classified broadly into two types: "final–goal" and "sub–goal." Especially, in this dissertation, we focus on enhancing the sub–goal by using *TBC-Cycle*.

- Finally, Section 4.4 describes two concrete examples of use–case of Team–Level Behavior Change Model: 1) Enhancing Team–Level Exercise Behavior Change and 2) Enhancing Team–Level Self–Report Activity.

Chapter 5

Sapplication Platform

This section describes a system design and implementation of Sapplication Platform. For constructing *TBC-Cycle*, large scale and long–term investigations are required in real teams. As a first step due to the investigate, we designed and implemented a platform called *Sapplication Platform* for applying and evaluating a team–level behavior change models to any team.

5.1 System Design

For large scale and long–term human–behavioral science, Hekler et al.[51] mentioned possibilities in HCI researches methods such as daily using the platform and big data (i.e., Evidence Activity Data), personalization using Machine Learning Technologies, semi– and/or automated–mobile human sensing technologies. In the other word, a platform which can be used in their daily activity and collect daily activity stress less is a powerful sensing and intervening, evaluating tools for deep human and team–level behavior change evaluation.

For realizing the platform, we propose Sapplication Platform. *Sapplication* is a coinage with "Supplement" and "Application;" On the platform, it provides an application (i.e., information) as a supplement for enhancing human behavior. As a very similar concept, *Information Medicine* was proposed by Nakashima [11]. However, the concept mainly focused on recovery a patient's condition to normal condition from bad condition. On the other hound, a goal of Sapplication is to enhance normal or good condition people to a more good condition by using information.

On the Sapplication Platform, researchers and users can execute following operations.

- Member management functions
- Applying sharing models and life-log data to optional teams
- Collecting evidence data

Figure 5.1 shows a procedure of platform usage. At first, 1) each user make an account on Sapplication Platform, and install a client application for intervention(see Figure 5.4). 2) At second, a master user makes team on platform's dashboard (Figure 5.3), and invites members from member management page as shown in Figure 5.3. 3) At third, a master user makes a Sappliment by Sapplication Maker (Figure 5.9.) 4) Finally, team members upload their activity data to Sapplication Platform, and the platform provides filtered information to members; which filtering depends on the applied *Sappliment*.

5.2 Implementation of Sapplication Platform

In this section, we describe system implementation of Sapplication Platform which is satisfied requirements (See Section 5.1. Figure 5.2 shows system architecture of

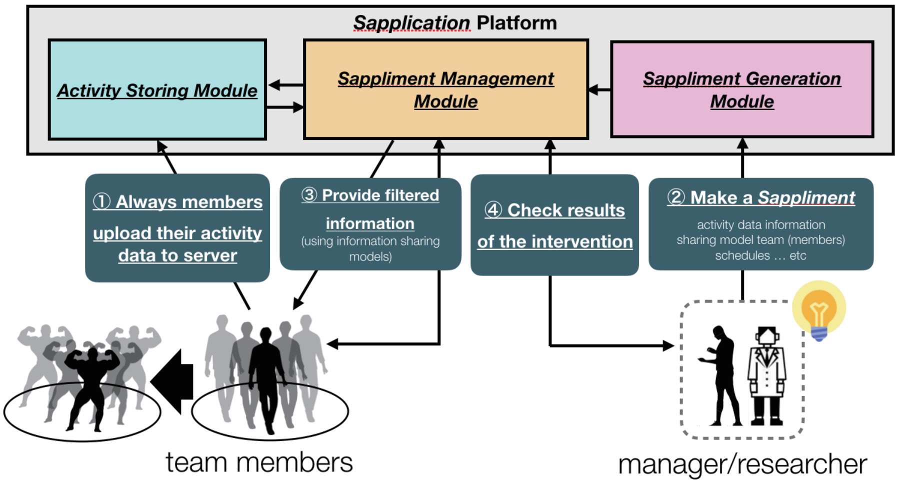

Figure 5.1: Concept of Sapplication

Sapplication Platform. The platform is composed three modules: **User Management Module**(see Section 5.2.1) and **Sappliment Management Module**(see Section 5.2.3), **User Data Collecting and Intervening Module**(see 5.2.2).

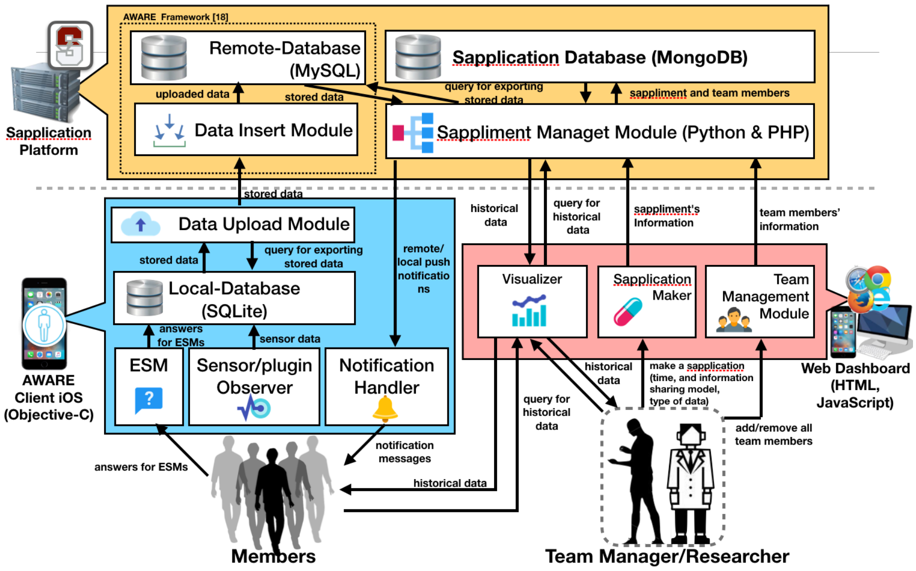

Figure 5.2: System Architecture of Sapplication Platform

The sever–side modules (i.e., User and Sappliment Management modules) on the platform is composed of HTML and JavaScript, PHP, Python. In the addition, the mobile client–side (i.e., User Data Collecting and Intervening Management Module) is composed by Objective-C.

5.2.1 User Management Module

User Management Module allows to managing team members and internal–teams in a team. Figure 5.3 shows the team member management page. On the page, a member can make own teams, and after making a team, the user will be a master user of the team. In the owner team, a master user can add/remove users to own team, and select a user role from “master” or “manager,” “member.” “master” access and change the all of the information in the team as an administrator. “manager” user can execute destructive operations such as “add/remove new users” and “make a new suppliment.” “member” can access to own information only. Optionally, “master” and “manager” users can make any internal teams for splinting interventions.

5.2.2 User Data Collecting Module

AWARE Framework [69] is mobile sensing framework for CMS researches, and also it is used in varies researches [80, 81]. Moreover, the framework can collect hardware (e.g., Accelerometer and GPS, Air-pressure)– and software (e.g., Battery and Screen, Network)–, human-based– (e.g., ESM and Keyboard, Microphone) data using mobile client. Table 5.1 shows supported sensors on the AWARE Framework iOS and Android.

In the addition to these default sensors, the framework allows for adding original plugins extensibility. However, the framework supports only Android. As we described in Section 3.3, in Japan, 72.45% of people are using iOS mobile phones. Therefore, for enabling more large scale evaluation and making more opportunities, we developed AWARE client iOS on his framework. Figure 5.4 is a screenshot of AWARE client iOS. The client is developed as a native iOS application by using Objective-C. The app can collect almost the same sensor data as the AWARE Android client (Table 5.1 shows supported sensor list on iOS client compare with Android.) and also, it is possible to manage by AWARE dashboard.

Category	Sensor/Event Data	Android	iOS
Movement	Accelerometer	○	○
	Linear Accelerometer	○	○
	Gravity	○	○
	Gyroscope	○	○
	Magnetometer	○	○
	Locations	○	○
	Activity Recognition	○	○
	Rotation	○	○
Social Media	Google Login	○	○
Communication	Phone Call	○	○
	SMS Messages	○	×
Environment	Weather (Web API)	○	○
	Barometer	○	○
	Temperature	○	×
	Ambient Noise	○	○
	Light	○	×
Device/Network	Battery	○	○
	Bluetooth	○	△
	Cell tower binding	○	×
	Screen on/off	○	○
	WiFi (WLAN BSSID)	○	○
	Installations	○	×
	Network	○	○
	Processor	○	○
	Proximity	○	○
	Timezone	○	○
User	ESM (Mobile Survey)	○	○

Table 5.1: Supported sensors on AWARE Framework [69]

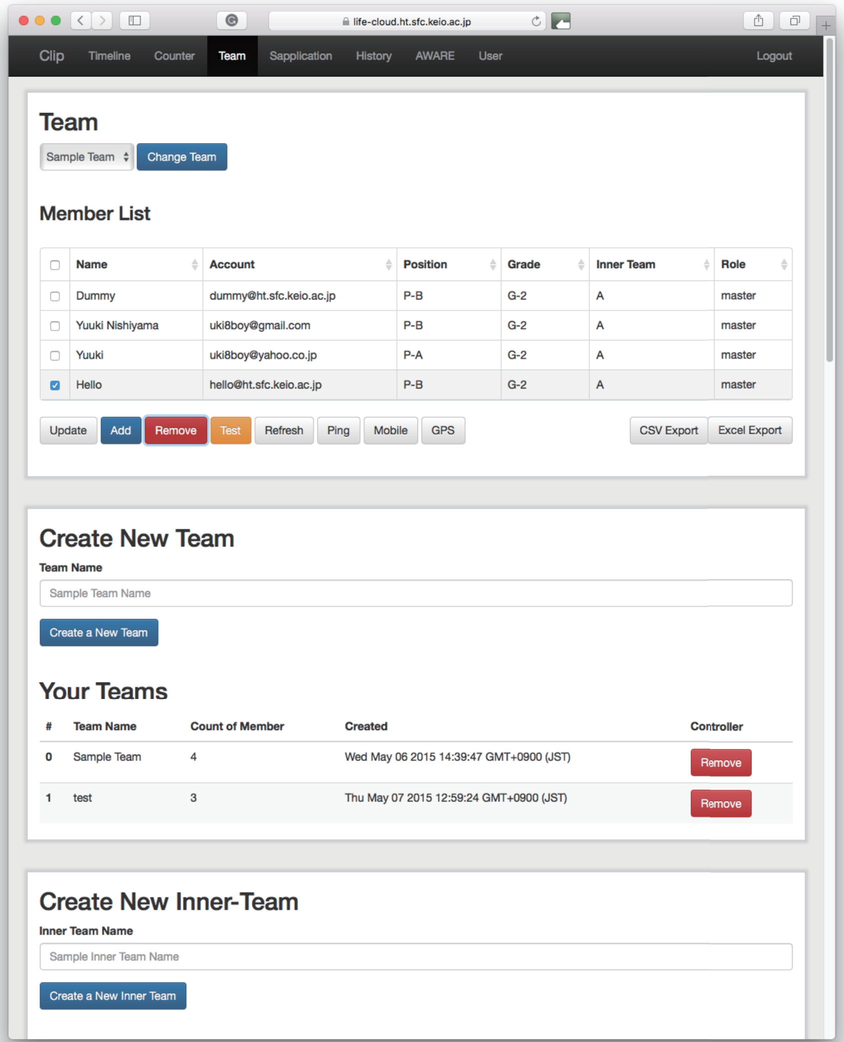

Figure 5.3: Screenshot of Team Manager

Researchers can release the client via AppStore[1] or install the client to iOS smartphone from Xcode[2]. AWARE Client iOS is an open source project. All of the developers are able to use it from GitHub under Apache License Version–2.

[1]https://itunes.apple.com/fi/app/aware-client-ios/id1065978412?mt=8
[2]https://itunes.apple.com/jp/app/xcode/id497799835?mt=12

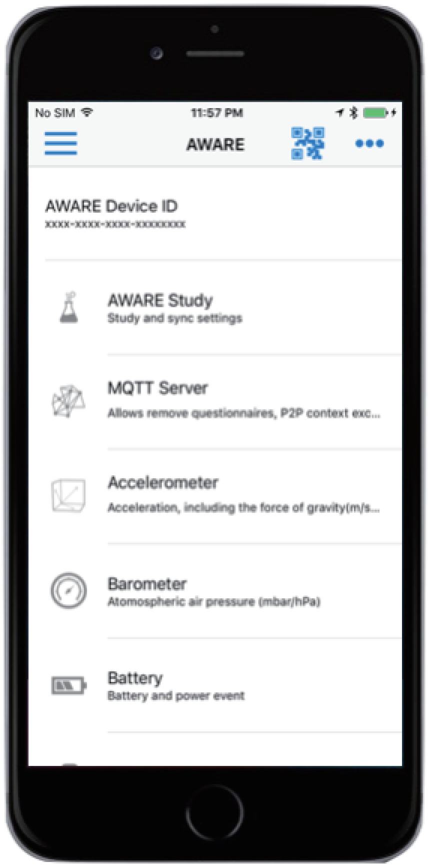

Figure 5.4: Screenshot of AWARE Client iOS

Figure 5.5 and Figure 5.6 show system architectures of iOS and Android AWARE client. iOS client is designed and implemented same structure with Android. Due to limitations on iOS, the iOS client can not communicate between third party applications except for applications which are developed by the same developer; then all of the plugins are implemented on iOS. Table 5.2 shows application release methods for iOS platform. For third–party developers who want to release their plugin, they have three ways to deploy it to participants. As a first way, if participants for their study is little (i.e., between 1 and 10 people,) the researcher can deploy AWARE client iOS via Xcode directly as a development application; this method is the speediest and easiest way to release it. Releasing AWARE client as an AdHoc application is a second way for experiment between 10 and 100 participants. iOS can compile as an AdHoc application on the Xcode. By using the app, you can release the app via web services such as a Flight[3] or DeployGate[4]. However, normal iOS developer account has a limitation for releasing the app for 100 devices and device registration is required. Using External–Tester function on TestFight, the apps can release to participants without the limitation with review by Apple during 60 days; the review takes 1–3 days. Using the Apple Developer Enterprise Program which is high–end iOS developer account and required $299 per year and a corporation, developers can release the app without the limitation and the apple's review. The third way is to release the app on AppStore; participants download the app from AppStore. In a study that has over 100 participants, releasing the app via AppStore is the easiest way to release and update the app to participants. However, it needs 1–7 days for a review by Apple.

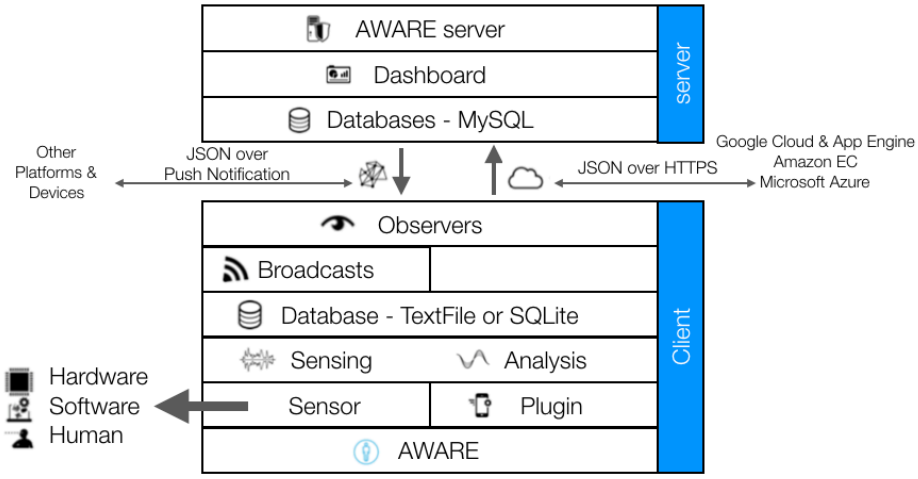

Figure 5.5: System Architecture of AWARE Client iOS

Figure 5.7 shows a system architecture of iOS ESM. If the iOS ESM is allowed on AWARE Dashboard, the sensor gets an ESM configuration from a selected server. Basically, the ESM sensor on AWARE client iOS uses the same ESM configuration (JSON format.) with AWARE client Android. Tutorial for making the ESMs are on following URLs [5] [6]. After downloaded the configuration file, iOS ESM sends ESMs

[3]https://developer.apple.com/testflight/
[4]https://deploygate.com/
[5]\http://www.awareframework.com/development-esms-on-aware-client-ios/
[6]http://www.awareframework.com/schedule-esms-for-aware-ios-client/

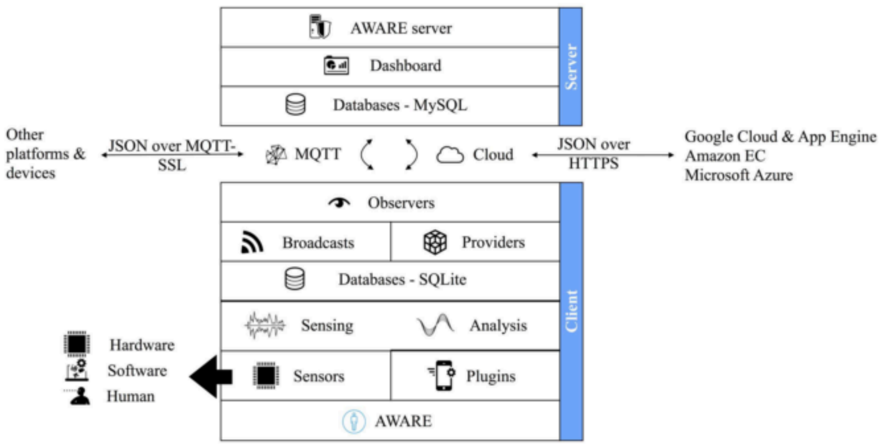

Figure 5.6: System Architecture of AWARE Client Android[69]

Table 5.2: Methods for Application Release on iOS platform

Method	UUID Registration	Deploy Platform	Apple's Review	Estimated Review Time	Account Fee	Software Update
AppStore	NO	AppStore	YES	1-7 days	99$	Automatic or Manual
DeployGate (AdHoc)	YES	DeployGate	NO	immediate	99$	Manual
TestFlight (Internal–Tester)	YES	TestFlight	NO	Immediate	99$	Manual
TestFlight (External–Tester)	NO	TestFlight	YES	1-7 days	99$	Manual
Apple Developer Enterprise Program	NO	URL	NO	Immediate	299$	Manual

based on the scheduled time.

AWARE Client iOS supports scheduled ESM function namely iOS ESM. As shown in Figure 5.8, iOS ESM has an ability to generate seven(7) types of ESMs such as (Free-Text(1),Radio-Button(2), Checkbox(3), Likert-Scale(4), Quick-Answer(5), Scale(6), DateTime-Picker(7)) which are same as the ESM function on Android client with triggered at certain time.

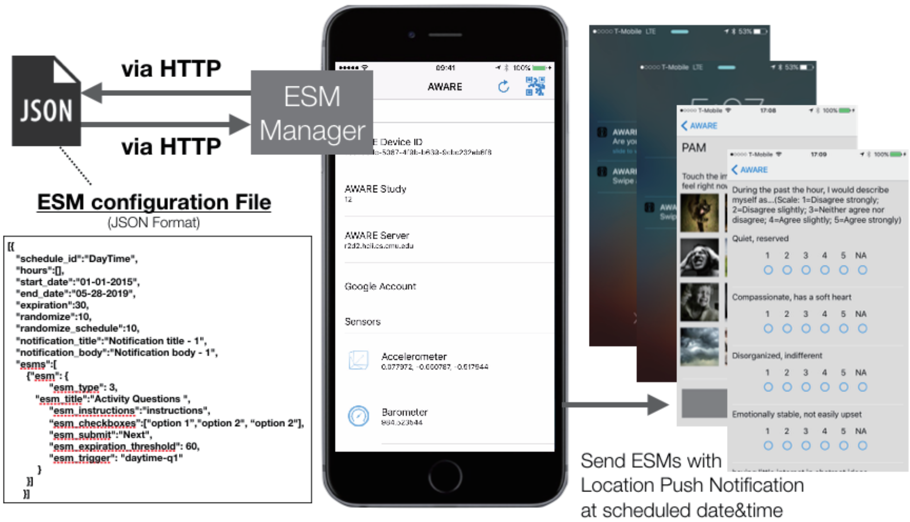

Figure 5.7: System Design of ESM for AWARE Client iOS

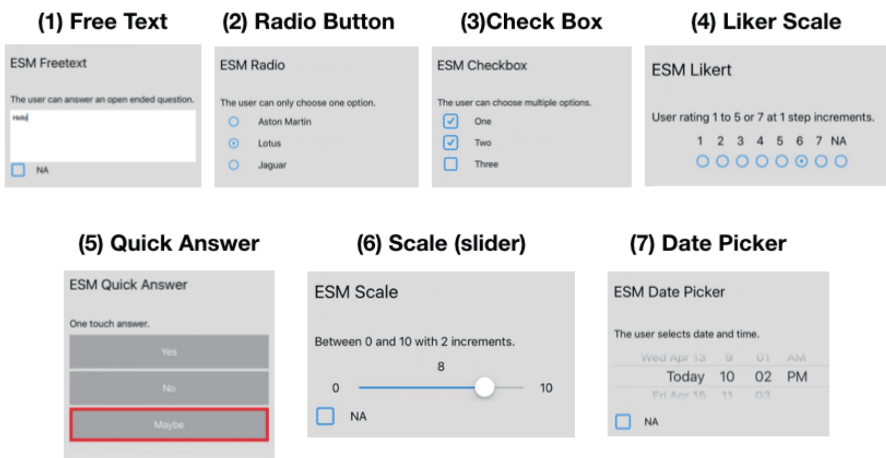

Figure 5.8: Supported ESMs

5.2.3 Sappliment Management Module

Sappliment Management Module allows making any Sappliment based on the stored activity data in the Sapplication Platform. Figure 5.9 illustrated a screenshot of the module. On the module, to make a *Sappliment*, team manager can select "information sharing model," "target inner–team(s)," "term," and "activity data for information sharing" on the dashboard.

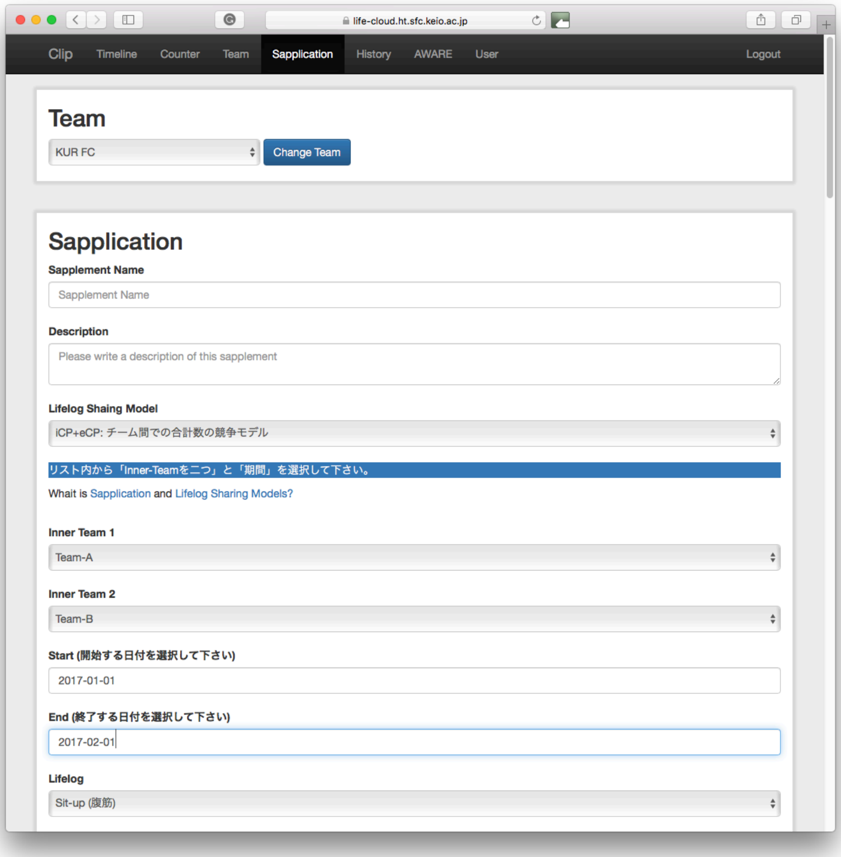

Figure 5.9: Screenshot of Sapplication Maker

First, a manager selects a type of information sharing model to make a new Sappliment. There is six selectable types (i.e., *IND, iCL, iCP, iCLP, iCL+eCP, iCLCP+eCP*) which is defined in Section 4. Second, the manager set a target inner–team(s) for the Sappliment. The inner–team(s) is made on the Team Management Module that is described on Section 5.2.1. A case of *iCL+eCP* and *iCL+eCLCP* model have to assign two teams because the model needs an enemy team for a team–level competition. Third, a term of the Sappliment (=team–level intervention) is set with *start* and *end* date. Finally, the manager selects activity data for information sharing from the stored data in the Sapplication Platform. As an option, the manager set a time to share the information via push–based notification function [7] on the mobile client if the manager needs to extend the Sappliment.

5.2.4 Data Visualization Module

This section describes data visualization modules on Sapplication Platform. The platform has two types of visualizations for manager and member which are set by team member management module. Figure 5.10 illustrates a screenshot of data viewer for a manager in a team. Moreover, Figure 5.11 shows a screenshot of data viewer for a team member.

The viewer for a team manager (Figure 5.10) provides team members information if the team members allow for accessing the data. As an example, a bar chart in Figure 5.10 shows a response count of ESMs in a day, and the each color in a bar shows types of answers. Team members can check the total ESM answers immediately.

On the other hand, a viewer for a tea member (Figure 5.11) provide only own data which is stored on the Sapplication Platform. In other words, the viewer does not provides other members information without Sappliment. In the case of Figure 5.11, the viewer provides own number of steps, number of exercises, moving distance a day, skin temperature, GSR, Heart Rate, and weather information around the member.

5.3 Procedure of Platform Usage

This section describes a procedure of Sapplication Platform. There is two types of users on the platform: *Manager* (which includes coaches, staff, and researcher) or *Member*.

The platform is used by following eight steps:

1. *Manager* makes an account on the platform.
2. *Member* makes a new team on the platform.
3. *Members* make their account and share their user name or email address to the team manager (Section 5.2.1).
4. *Manager* adds the account to the created team. (Section 5.2.1).

[7] A Programing Guide for Apple Push Notification service (APNs): `https://developer.apple.com/library/content/documentation/NetworkingInternet/Conceptual/RemoteNotificationsPG/APNSOverview.html#//apple_ref/doc/uid/TP40008194-CH8-SW1`

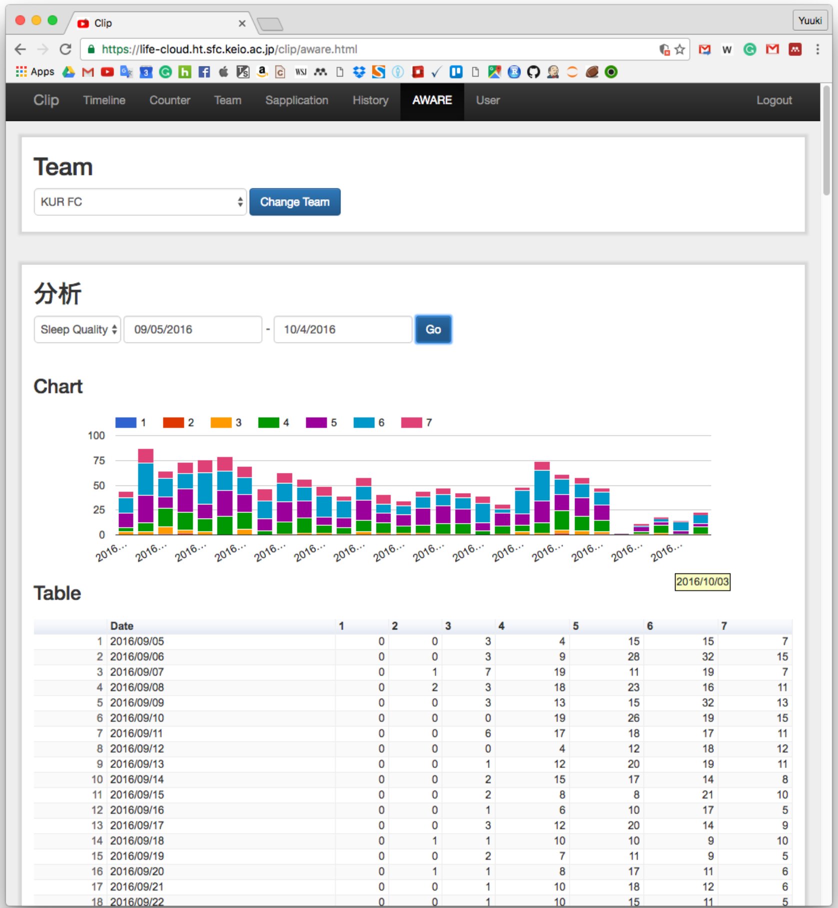

Figure 5.10: Screenshot of Data Visualization Module for Manager

5. *Manager* makes sub–teams and allocates the members to the sub–teams. (Section 5.2.1).

6. *Manager* makes a Sppliment and applies it to each sub–teams for enhancing team–level behavior. (Section 5.2.3)

7. *Members* check the other members activities or own activities through characteristics of the applied Sappliment.

8. *Manager* checks the effects of the Sappliment via the data visualization viewer

Figure 5.11: Screenshot of Data Visualization Module for Member

(Section 5.2.4).

5.4 Summary

This section describes the system design and implementation of Sapplication Platform for long–term and large–scale intervention to a real team. The key contents of this section is below:

- **Sapplication Platform** uses information as a supplement for enhancing behavior change.
- **Sapplication Platform** is designed for large scale and long term intervention study with multiple intervention based on the concept of CMS research.

- **Sapplication Platform** is composed of "User Management" and "User Data Collecting and Intervening," "Sappliment Management" Module.
- As a **mobile client**, we develop AWARE client iOS as an open source software.

Chapter 6

Exercise Study: Promoting Team-level Exercise Behavior Change

This chapter describes a first study for measuring effectiveness of information sharing models in a baseball team and a research group. For measuring it, we develop a plugin called "Aaron2" for counting and sharing exercises activity among team members on Sapplication Platform, and conducts an in–the–wild user study with 64 participants over a period of three weeks.

First, Section 6.1 shows a target team–level behavior change in this study. A study procedure is described in Section 6.2. Third, Section 6.3 indicates result of the study. Finally, based on result of the study, Section 6.4 discusses the exercise study.

6.1 Target Team–level Behavior Change

The goal given to the participants was to increase their sit-up count. We designed the experiment to establish the differences in the effect of the six kinds of proposed lifelog sharing models. Increasing the number of sit-ups is important for the health of all the team members. For example, sit-ups are effective for preventing backache, and strengthening the abdominal muscle leads to improved sports performance.

Further, in this evaluation, our target teams were "existing teams," which differ from "instant teams" that are gathered by public offering. In "instant teams," human relationships are not sufficiently fully formed. In our evaluation, we focused on the "existing teams" because they already have comprise relationships formed between members.

6.1.1 Schedule of Information Sharing

Aaron2[1] is a web application, created for both the iOS and Android platforms, which counts and tabulates users' daily exercise activities. For example, with Aaron2, a user can count up his/her exercise, such as number of sit-ups, push-ups, or squats, and share with other team members.

To evaluate our proposed lifelog sharing models, Aaron2 was given the capability of to use one of the models selectively for each user. From the user's viewpoint, according to the configured model, different types of lifelog data, such as their activity record or another member's record, could be displayed on the screen. Aaron2 is designed as a simple framework to enumerate the various activities on actual users' devices in a similar way. In addition, this enumerate framework has the possibility of miss alignment between real speed and counting speed. However, this is possible with all users. Thus, in this sense, Aaron2 can disregard the miss alignment possibility.

Figure 6.1 shows the process of interaction between an user and Aaron2. Firstly, in 1) and 2), the user login to Aaron2 using his/her mobile phone. At the same time, 3) and 4), Aaron2 shows other members' activities based on the selected lifelog sharing model. Secondly, 5)–7), during the exercise session, Aaron2 generates beeping sounds at regular intervals so that the user can perform their exercise by following the sounds, as shown in Figure 6.2. In addition, in this experiment, we setup one training set as 30 sit-ups. At the end of the training set, 8) and 9), Aaron2 automatically or manually

[1] Aaron2 (http://life-cloud.ht.sfc.keio.ac.jp/~tetujin/aaron2/)

stops the beeping sound and enumerates the user's activities. The user can also use Aaron2 to assist with his/her exercise multiple times in one day. Finally, 10) and 11), Aaron2 shows other members' activities based on the assigned lifelog sharing model.

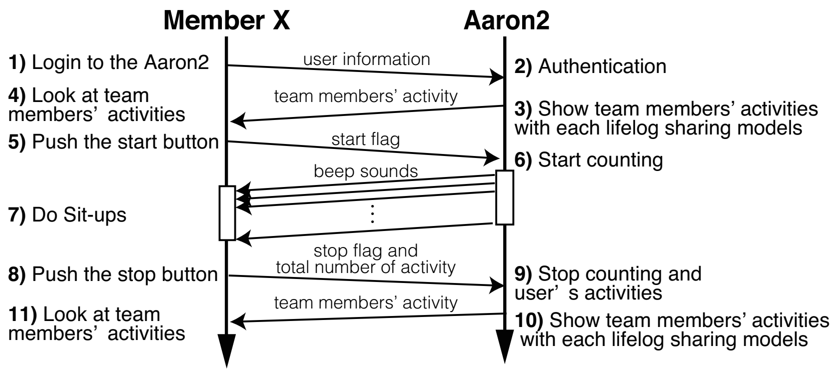

Figure 6.1: Process of interaction between an user and Aaron2

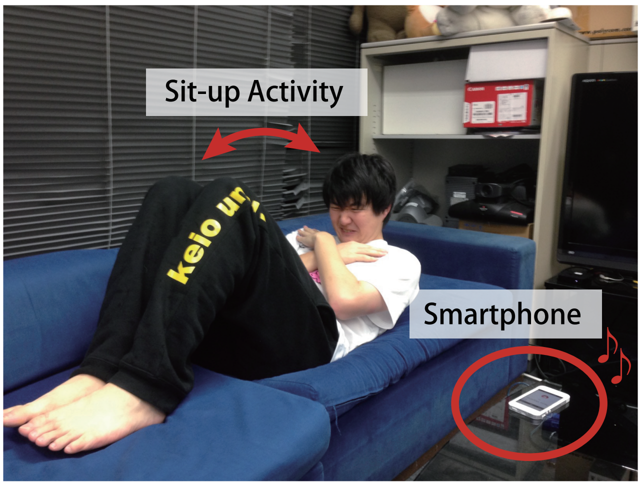

Figure 6.2: Usage example of Aaron2 in the user study

6.1.2 Used Information Sharing Models

This application comprises a *Top Page* (Figure 6.1.2), *Application Page* (Figure 6.1.2), *Settings Page*, and *Activity Page* (Figure 6.4). *Top Page* manages login information and displays the team activities goals, such as the number of sit-ups to be achieved by the team. *Application Page* provides functionality of exercise activity counter. When a user pushes a red button at the center of the screen, Aaron2 starts counting. When the user pushes the red button again, Aaron2 stops counting and uploads the activity record to the server. In *Setting Page*, users can set up the type of beeping sound, the sound interval, and the maximum sound count of a single set by themselves. Users can configure their exercise according to their own performance and condition. *Activity Page* shares other team members' activity count based on a proposed lifelog sharing models configured to the user respectively. Figure 6.4 shows the information displayed on the *Activity Page* for each of six sharing models.

We used jQuery Mobile 1.1 [82] for user interface framework and the Google Chart Tools [83] for the chart.

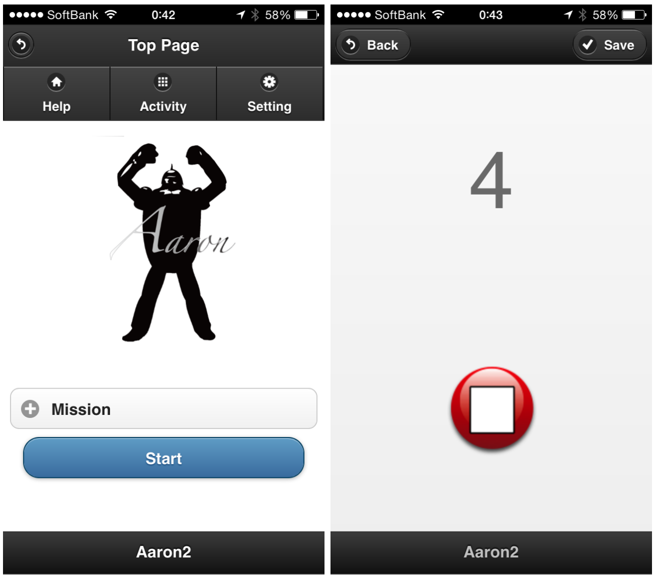

Figure 6.3: Screenshots of *Top Page* and *Application Page* in Aaron2

6.1.3 Team and Model Configuration

We focused on the Keio University Baseball Club (hereinafter referred as the **baseball team**) and the computer science laboratory at Keio University (hereinafter referred as the **laboratory team**) as target team for our first experiment.

The baseball team [2] is one of the historical baseball team in Japan. The team was established in 1888 as the first generation of a baseball club in Japan (Japanese

[2] `http://baseball.sfc.keio.ac.jp/`

baseball history is started from 1884.). Moreover, the team is one of the strong baseball clubs which has won the college championship six times in Japan and produced lots of professional baseball players. Due to promoting their baseball skills, they have "six–days practice" and "one–day rest" in a week during baseball season (February to June and August to December), and live in their dormitory with all team members.

The baseball team and laboratory team consist of 32 male members respectively. These members were chosen from the original team members (the baseball team had 147 members, and laboratory had 52 members) who agreed to this experiment. The average age of laboratory team members was 24.45, and that of baseball team members was 19.63. Further, the laboratory team comprised 20 bachelor students, six master's students, three Ph.D. students, and three young staff members (in their thirties). The baseball team comprised 32 bachelor students. Moreover, the laboratory team members' average of sports experience at sports team was 5.62 years and that of the baseball team members' was 11.18 years.

The aim of this experiment was to investigate the effect of the six types of proposed information sharing models. Therefore, we created fixed eight groups comprising four persons each group (A) to (H) for each team, with team members. Each team was assigned one of the six kinds of lifelog sharing models as shown in Table 6.1. Since the *iCL-eCP* and *iCLCP-eCP* models require opposing opponent teams, we assigned two teams to those models.

Table 6.1: Correspondence of Each Group and Information Sharing Models

Information Sharing Models	Laboratory	Baseball Club
IND	Lab-A	Baseball-A
iCL	Lab-B	Baseball-B
iCP	Lab-C	Baseball-C
iCLCP	Lab-D	Baseball-D
iCL+eCP	Lab-E,F	Baseball-E,F
iCLCP+eCP	Lab-G,H	Baseball-G,H

6.1.4 Dataset

As a dataset for an evaluation, this study collects following data:

TP Number of sit-ups by each member

CL Comfortable level from questionnaire

The participants answered the questions using a 5-point Likert scale (5-Strongly Agree, 4-Somewhat Agree, 3-Neutral, 2-Somewhat Disagree, 1-Strongly Disagree). The survey comprised the four questions as shown in Table 6.2. The participants had to answer Questions 1, 2, and 3 using the 5-point Likert scale, and Question 4 using free description. Question 1 was, "*How do you feel about activity sharing using the application?*" and Question 2 was, "*Do you want to use this application continuously?*". Questions 1 and 2 relate to discomfort with information sharing. Question 3 was, "*Do you feel pressure from other members?*" This question relates to pressure from team members. Question 4 was, "*Please write about an impressive event witnessed during the evaluation*". The user study was conducted from December 6th to 27th in 2013.

Table 6.2: Questionnaires about Level of Comfort Using the System

Questionnaire Number	Question
Q–1	How do you feel about activity sharing using the application? (very uncomfortable · uncomfortable · normal · comfortable · very comfortable)
Q–2	Do you want to use this application continuously? (strongly no · no · normal · yes · strongly yes)
Q–3	Do you feel pressure from other members? (strongly yes · yes · normal · no · strongly no)
Q–4	Please write about an impressive event observed during the evaluation. (free description)

6.2 Experimental Procedure

Figure 6.5 illustrates a study procedure of the exercise study.

On the first day, we held a meeting with all participants. At this meeting, we introduced them to the user study, usage of the Aaron2 application, and the group configuration. We gave a questionnaire to each participant inquiring about his/her goal for number of daily sit-ups. We also collected signed consent letters from all participants.

The user study started on the same day for all 64 participants. During the study period, each participant utilized his/her iOS or Android smartphones for the to use Aaron2. The participants were required to open Aaron2 at least once per day, and they were able to use it as often as they desired. Offline information exchange on exercise performance across groups and teams was prohibited.

At the end of three weeks, on the final day, we conducted another survey of all of the participants on the usability of Aaron2.

6.3 Results

In this section, we describe and consider the results of inspection of team total performance (TP) and the comfort level of lifelog sharing (CL).

6.3.1 Influence on Team Total Performance

This subsection describes and considers the results of TP. Figures 6.6 and 6.7 show the number of sit-ups achieved by each team in the eight groups. In the figures, the vertical axis signifies the cumulative number of sit-ups and the horizontal axis signifies the dates of the experiment. The values at the end of the horizontal axis are the total number of sit-ups achieved by each team in this experiment.

Based on the results above, our analysis showed several significant differences between the six proposed models.

IND as the baseline

All models with information sharing model between users (*iCL*, *iCP*, *iCLCP*, *iCL+eCP* and *iCLCP+eCP*) outperformed *IND*, the model without any lifelog sharing. In particular, the *iCL+eCP* model had 588% better result than the *IND* model. Further, the average value of all models other than *IND* had a 324 % better result than the *IND*. Based on the fact that the *IND* model is actually equivalent to the individual behavior change, this result implies that team-based behavior change is clearly more effective than individual-based behavior change.

Competition elements

The models with "competition" element, such as *iCP*, *iCLCP*, *iCL+eCP*, and *iCLCP+eCP*, showed better results than the *iCL* model. This indicates that use of internal collaboration solely is not effective and with use of some additional "competition" elements, either iCP or eCP, can be expected to reveal even better performance.

Number of lifelog sharing techniques

The *iCLCP+eCP* model, which has the largest number of lifelog sharing techniques shared among teams and team members, did not reveal the best result and actually underperformed compared to other models with fewer lifelog sharing techniques (*iCL*, *iCP*, *iCLCP*, *iCL+eCP*). This implies that the performance of team behavior change is not subject to the number of lifelog sharing techniques to be shared.

Comparing two "external competition" models

Comparing two "external competition (eCP)" models, *iCL+eCP* and *iCLCP+eCP*, the *iCL+eCP* model without "internal competition" element performed better. Figure 6.8 shows detailed user-by-user comparison between two models. The standard deviation of *iCL+eCP* (459.71) was much larger than that of *iCLCP+eCP* (190.67). In the *iCLCP+eCP* model, individual team members could access to the activity data of other team members. Thus, with the effect of internal competition in a team, all team members are considered to have made the exercise effort more evenly than the members of the *iCL+eCP* model, where internal competition does not occur.

Moreover, we compared and analyzed weekly changes in the amount of activity between two models (*iCL+eCP* and *iCLCP+eCP*). Figures 6.9 and 6.10 show the weekly standard deviation of *iCL+eCP* and *iCLCP+eCP*. The standard deviation of *iCL+eCP* decreased in the first to the third week. Furthermore, the standard deviation of *iCLCP+eCP* did not change in the first two weeks. However, in the second to the third week, the standard deviation of *iCL+eCP* was decreased.

Team goal and task setting

As shown in Figures 6.6 and 6.7, the TP of six groups of the Baseball Team (excluding Baseball-A (*IND*) and Baseball-B (*iCL*)) is higher than the TP of all the groups in the Laboratory Team. All teams used the same lifelog sharing models for each groups, but the TPs of the baseball and laboratory teams were different. This result indicates that the types of tasks are important for promoting team behavior change. In this experiment, we used real teams to promote "Sit-up activity." In the goal of the baseball team, sit-up was meaningful activity such as to "preventing injury," "improvement of sport skill," and "improvement of body balance." Therefore, the difference between "baseball team" and "laboratory team" was due to the difference between "team goal" and "task." In other words, using the task of closely related team goal is effective for promoting team behavior change.

Sustainable behavior change

Table 6.3 shows the result of weekly change in TP for the baseball team. It is clear from Table 6.3 that *iCLCP* almost maintains their TP over the three-week period. However, the values of most models' TP decrease sharply in the third week. For the baseball team, in particular, the value of TP in *IND* and *iCP* is zero in the third week.

As a result, in the case of a simple task such as "sit-up," TP shows the possibility of being maintained during the multi-week period. On the other hand, using the proposed models proves effective for team-level behavior change for only two weeks. To realize sustainable team-level behavior change, lifelog sharing models need to use other individual behavior change techniques (e.g., "ranking," "reward," "notification") that motivate users.

Table 6.3: Weekly TP of each lifelog sharing models in baseball team

Lifelog sharing model	1st week	2nd week	3rd week	Total
IND	352 (1)	118 (0.34)	0 (0)	470
iCL	260 (1)	285 (1.1)	170 (0.65)	715
iCP	795 (1)	647 (0.81)	0 (0)	1142
iCLCP	325 (1)	372 (1.14)	314 (0.97)	1011
iCL+eCP	943 (1)	859 (0.91)	403.5 (0.43)	2205.5
iCLCP+eCP	555.5 (1)	444.5 (0.8)	151.5 (0.27)	1151.5

6.3.2 Influence on Comfort Level

Table 6.4 shows the result of the questionnaire given to the baseball team. Further, Table 6.5 shows that impressive episodes (Q4) came from the participants during experiments. These episodes are written in the original text.

Table 6.4: Result of questionnaires given to baseball team

Lifelog Sharing Model (team)	Q1	Q2	Q3	CL
IND（Baseball-A）	2.75	2.25	4.25	3.08
iCL（Baseball-B）	3.50	3.25	2.75	3.17
iCP（Baseball-C）	3.25	3.25	3.25	3.25
iCLCP（Baseball-D）	3.50	3.50	3.00	3.50
iCL+eCP（Baseball-E&F）	3.00	3.00	4.25	3.42
iCLCP+eCP（baseball-G&H）	2.75	2.75	3.13	2.88

Table 6.5: Impressive episodes for participants

Lifelog Sharing Model	Impressive episodes for participants (Q4)	
	Positive feedback	Negative feedback
IND	*"My motivation was improved by the system"*	*"I gave up periodic sit-up activities after I had concentrated over a particular short term."*
iCL	No impressive episodes	*"I felt that keep doing sit-ups is very hard."*
iCP	*"I came to enjoy by using this system."* *"I could not see the sit-up counts of other members. So, I felt that I had to do more sit-ups."* *"One day, I did over 600 sit-ups and felt happy and fulfilled because other team members were very surprised. "*	*"I could barely achieve the required number of sit-ups."*
iCLCP	No impressive episodes	*"I did close to 1000 sit-ups, and felt a tension in my neck as a result."* *"My motivation decreased when other members did not do enough sit-ups."*
iCL+eCP	*"I need more team feeling as compulsion."* *"When I opened the application, I felt I had to do the sit-ups."*	No impressive episodes
iCLCP+eCP	*"I enjoyed the competition with my teammates very much."*	*"I felt pressure from other members."* *"When I didn 't do sit-ups and others did, I felt very uncomfortable."*

CL and *iCLCP* values are higher than those of *iCL+eCP*, *iCP*, *iCL*, *IND*, and *iCLCP+eCP*. In Question 1 and 2 – the questions about discomfort with lifelog sharing – Baseball-A (*IND*) and Baseball-G (*iCLCP+eCP*) replied it with a value less than 2.75.

No lifelog sharing

Some participants of the *IND* model had positive opinions. On the other hand, some other members had negative opinions and gave up on sit-up activities. These phenomena are not seen in the lifelog sharing models that use competition and collaboration techniques (*iCL, iCP, iCLCP, iCL+eCP, iCLCP+eCP*). These results suggest that absence of lifelog sharing leads to reduced sustainable application use motivation.

> *Member of IND: "My motivation was improved by using this system!"*

> *Member of IND: "I gave up periodic sit-up activity after I had only concentrated over a particular short term."*

Social Pressure of excessive lifelog sharing

Sustainable motivation similarly declined with *iCLCP+eCP* techniques comprising internal and external competition and collaboration lifelog sharing techniques. In the questionnaire about impressive episodes for *iCLCP+eCP*, one participant had the positive opinion shown below. Conversely, other members of *iCLCP+eCP* had negative opinions (also shown below). These results indicate that using excessive competition is detrimental to the promotion of team behavior change, because using excessive competition elements lead to high social pressure.

> *Member of iCLCP+eCP: "I enjoyed the competition with my teammates very much."*

> *Member of iCLCP+eCP: "I felt pressure from other members."*

> *Member of iCLCP+eCP: "When I didn't do sit-ups and others did, I felt very uncomfortable."*

Competition between teams

Question 3 was able the pressure that a user felt from other members. The results for Baseball-A (*IND*), Baseball-E (*iCL+eCP*), and Baseball-F (*iCL+eCP*) showed more than four points. Further, from the following impressive episodes, *iCL+eCP* had positive opinions about competition between teams. The social pressure of *iCL+eCP* was lower than other lifelog sharing models. In this sense, participants' behavior change in *iCL+eCP* was not a passive behavior change but an active behavior change. Further, considering TP, *iCL+eCP* was the best most for promoting activity. Thus, in the case of using a lifelog sharing model for competitive teams such as a baseball team, the element “competition element between teams” is very effective.

> *Member of iCL+eCP: “I need more team feeling by compulsion.”*

> *Member of iCL+eCP: “When I opened the application, I felt that I had to do the sit-ups.”*

6.4 Discussion

In this section, we discuss problems and associated future work.

6.4.1 Team Design

Group activities change depending on roles [84], such as readers, observers, and coaches. Moreover, differences in gender and culture result in important research questions. In this study, participants did not have clear roles. Furthermore, all participants were men from Japan.

Different roles, genders, and cultures may have a different impact on the lifelog sharing models that are ideal for the team. Therefore, mixed roles and human type evaluations are necessary in future work.

6.4.2 Characteristics of Each Information Sharing Model

The results show that each model has “weak points” and “strong points.” Thus, each lifelog sharing techniques should be used in accordance with a team’s needs and situations. For example, of the six models, the *iCLCP+eCP* model has the highest TP value and the lowest CL value. Thus, using *iCLCP+eCP* to promote only TP (no CL) could be desirable.

6.4.3 Long-Term Experiments and Analysis

In these experiments, we used the application for three weeks, and evaluated the effect of each lifelog sharing models for team behavior change using TP and CL.

However, these evaluations of models for promoting team behavior change are deficient as experimental terms and evaluation methods. Construction of definitive models is needed for long-term evaluations such as “Comparisons of each model’s effect before and after” and “Daily and monthly term analysis.”

In addition, the introduction of novel technologies has been known to garner substantial interest for a short time then wane over time. Figure 6.11 shows that the daily active user rate decreased with time. The average active user rates throughout the user study period were 44.35% (baseball club) and 38.84% (laboratory). Moreover, participants had commented such as *“I often forgot to access to the application; therefore I did not do any sit-ups.”*.

The decrease in the daily active user rate is considered to lead to a reduction in the promotion of team behavior change in the long term. Existing individual behavior change techniques (e.g., “ranking,” “reward,” “notification”) have been shown to be useful in improving and maintaining the daily active user rate. These techniques can be used simultaneously with lifelog sharing models at the same time. For example, one of the functions based on gamification, such as setting an individual weekly goal and reward system, could be ideal. In future works, comparison with existing behavior change techniques needs to be carried out.

6.4.4 Constructing a Platform to Promote Team Behavior Change

In this experiment, we proposed six types of lifelog sharing models and analyzed the effect of each on teams. However, our ultimate goal is actually the construction of a team behavior change model that utilizes various types of elements. In our future works, we will construct a platform that promotes team behavior change and combines various types of lifelog data, 2) teams, and 3) behavior change promotion techniques which include existing techniques (e.g., “ranking,” “reward,” and “notification”) and approaches[1, 85]. We will also construct team behavior change promotion models and conduct long-term evaluations with more and various types of teams using that platform. Further, one of our future research directions is to explore more techniques for behavior change, such as social networking competitions.

6.5 Summary

In this section, we described an experiment (namely **Exercise Study**) for measuring influence on information sharing (i.e., *IND, iCL, iCP, iCLCP, iCL+eCP,* and *iCLCP+eCP*) for team-level exercise behavior change with a baseball–team and a research laboratory team in a university. In this study, the Sapplication Platform shares the progress of other members amount of sit-up activities among team members, and also we analyzed the effect of the information sharing models.

The key contents of this section are below:

- We used six different types of lifelog sharing models (i.e., *IND*, *iCL*, *iCP*, *iCLCP*, *iCL+eCP*, and *iCLCP+eCP*) for increasing their number of sit-ups (exercise) as a sub–goal in this study.
- For measuring it, we developed a plugin namely "Aaron2" for counting and sharing exercises activity among team members on Sapplication Platform.
- As a first study for measuring the effectiveness of information sharing models, we conducted a team-level intervention study with 64 participants(i.e., members of a baseball team and a research group) over a period of three weeks.
- The evaluation results obtained suggest that lifelog data closely related to the performance indicator of the team effectively enhance team behavior change.
- Furthermore, of the six kinds of proposed models, the external competition concept model (*iCL+eCP*) was the most effective for teams in competitive situations, such as sport teams.

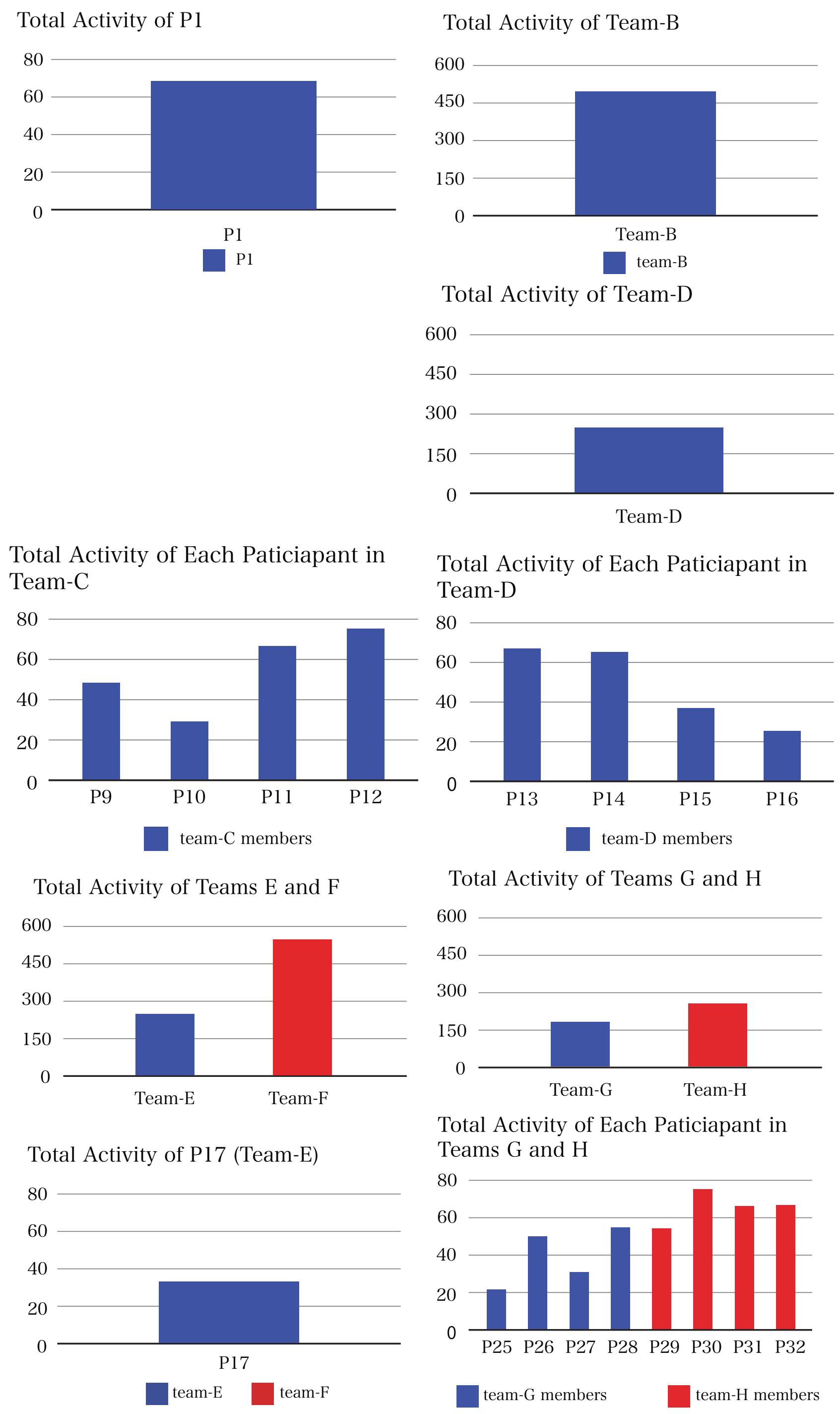

Figure 6.4: Components of the *Activity Page*

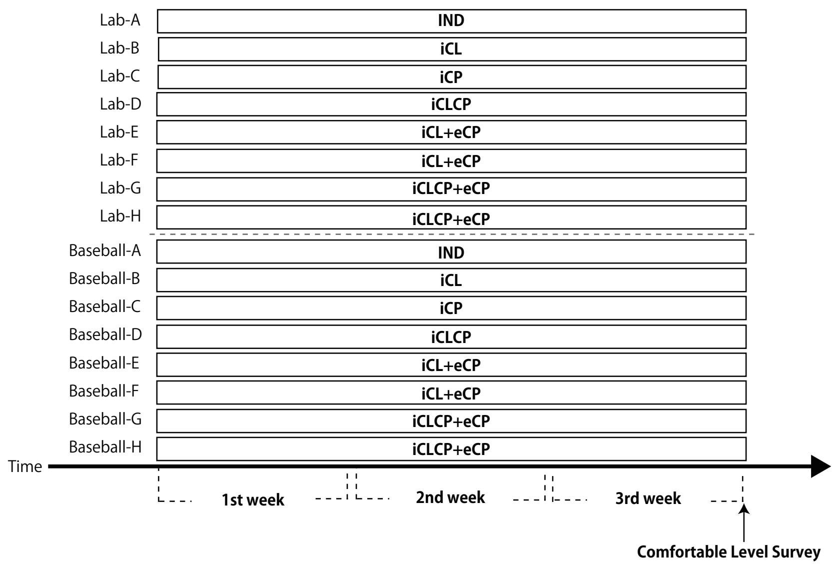

Figure 6.5: Experimental Procedure of Exercise Study

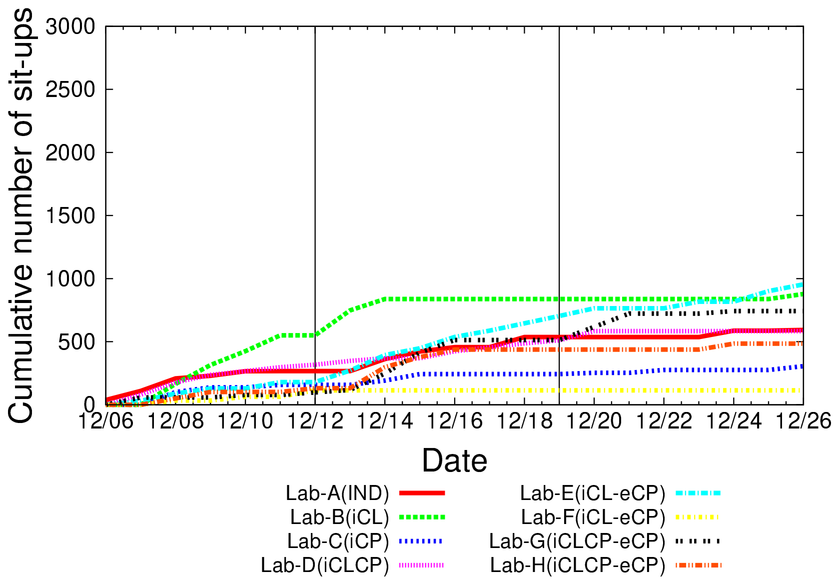

Figure 6.6: Sit-up Activity by the Laboratory Team

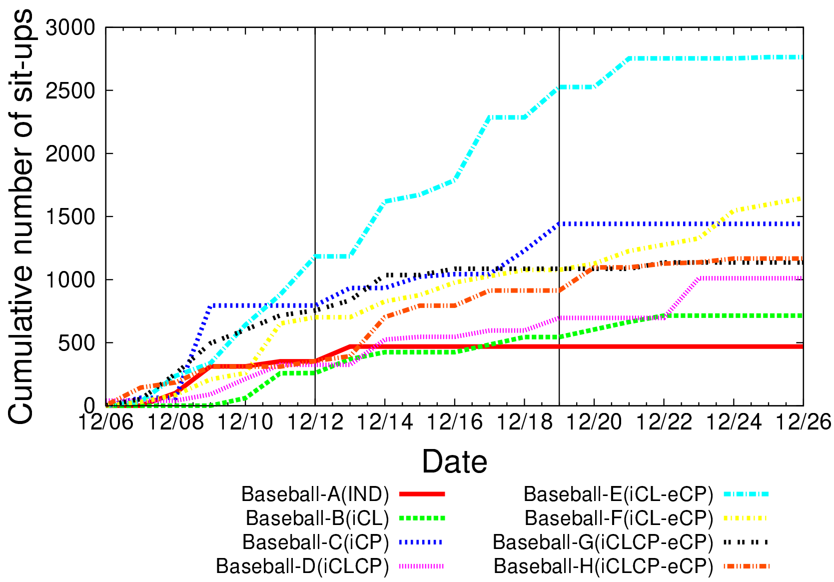

Figure 6.7: Sit-up Activity by the Baseball Team

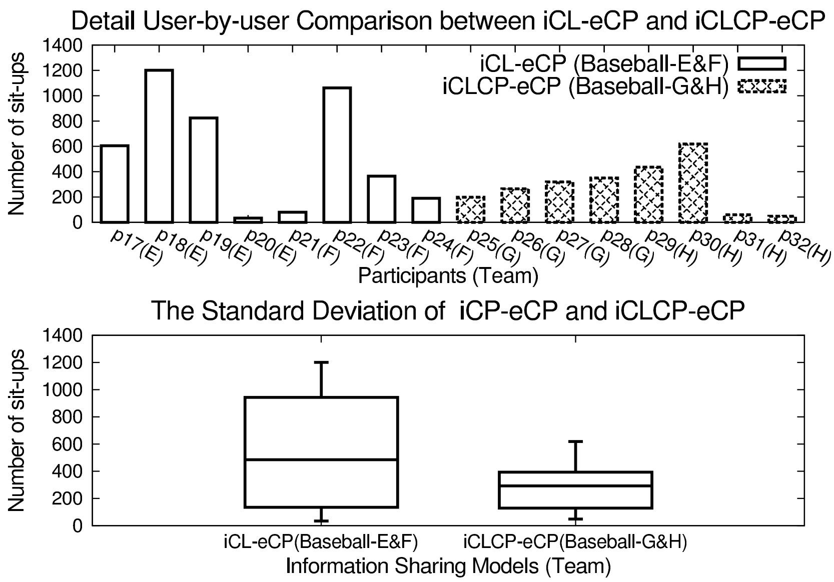

Figure 6.8: Comparison between *iCLCP+eCP* and *iCL+eCP*

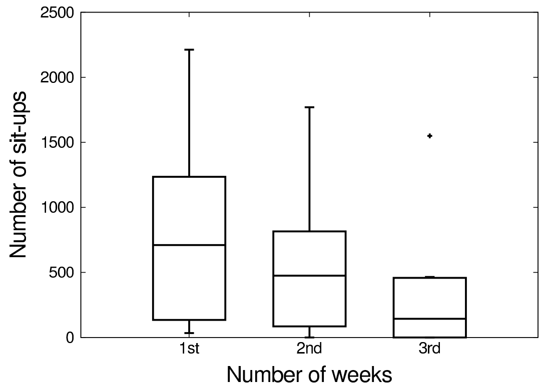

Figure 6.9: Comparison with weekly standard deviation of *iCL+eCP* in baseball team

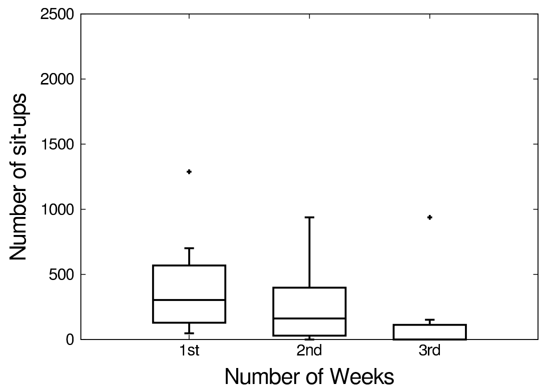

Figure 6.10: Compare with weekly standard deviation of *iCLCP+eCP* in baseball team

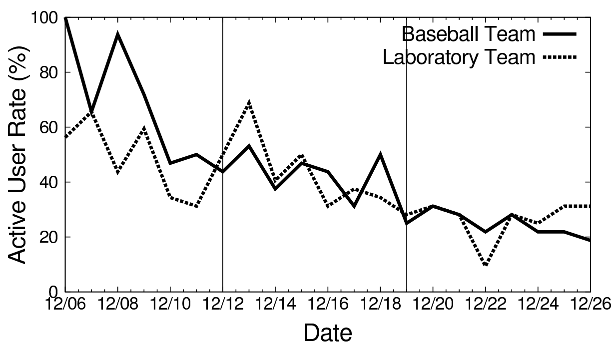

Figure 6.11: Daily active user rate of Aaron2 during the experiment

Chapter 7

Self–Report Study: Enhancing Team–Level Self–Report Activity

This section describes Self–Report Study which is measured influence on information sharing for team-level self-report activity behavior change. We developed a plugin for self-report activity sharing on Sapplication Platform, and used it in a rugby team for retrieving their physical condition by coaches.

7.1 Target Team–level Behavior Change

From a viewpoint of coaches in the sports team, observing players physical and mental condition promptly is a high priority task for preventing serious injury. Especially, for sports which include contact such as rugby and american football, soccer, failing concentration and increasing fatigue have a risk to conduct fatal injury (e.g., fracture and concussion, spinal cord injury.) Due to preventing the accident, physical trainer and coaches need to observe all players' condition. Nowadays, by the spread of sensor-technologies (see Section 2.1), we can collect variety types of information. However, the human factor is still important data for understanding the human condition. In fact, The Japan National Rugby Team are collecting physical and mental conditioning data every morning with web-based survey system in addition to sensor data. Besides, collecting the condition data quickly and immediately without human assistance that reduce a burden of data collection by coaches, and allow to change training and practice menu flexibly based on the players' condition data.

Through our interview, Chihiro Ota who is a Strength & Conditioning (S&C) Assistant Coach in Japan National Rugby Union Team and also a head coach of S&C in Keio University Rugby Football Club said about an importance of collecting subjective condition data quickly as follows;

> *"From the standpoint of S&C, to collect and manage "subjective" condition data is important in addition to values such as "objective" mileage and the like in order to manage the condition of the athlete. Especially at top-level players, the performance levels among the players is so close.*
>
> *Therefore, to arrange their athletes' peak performance to the game without injury and fatigue is extremely important to achieve the final team goal. For example, by collecting subjective data (condition data) of players in the morning, we can control the amount of daily physical / skill training and provide effective practice for games such as prevention of athlete overwork etc."*

Existing tools (e.g., CoachMePlus[1], ONE TAP SPORTS[2], CLIME Factory[3] allow to collecting the information via the web or mobile client. However, the tools have

[1] https://coachmeplus.com/
[2] https://www.one-tap.jp/top
[3] http://www.climbfactory.com/

only common– or no–reminder function. If a player(i.e., professional players) has a high motivation and/or benefit to understanding his/her condition by themselves, and the team has rich human–resources for handling players input, coaches can collect the information by using only the common reminders. However, due to human–motivation, we expect hard to collects the data in an amateur team such as teams in university, high school, junior high school using above functions.

The second study (**Self–Report Study**) focus on enhancing team–level self-report behavior change by using progress sharing.

7.1.1 Schedules of Information Sharing

Figure 7.1 shows notification schedules for sharing other members' progress of answers. Generally, in Self–Report Study, Sapplication Platform provide progress information between 8 and 12 AM as **Reminding Notification**, and 8 PM as **Result Notification**. Reminding Notification sends notification each 30 minutes between 8 and 12 AM, until the user answers the self–condition check survey; In this sense, if a user did not answer the survey, the user revived notification 8 times. As shown in Figure 7.2, if the user does not answer the survey before 12 AM, Sapplication platform stop to send Reminding Notification. Moreover, the user answer the survey before 8 AM, Sapplication platform does not send notification (Figure 7.3.)

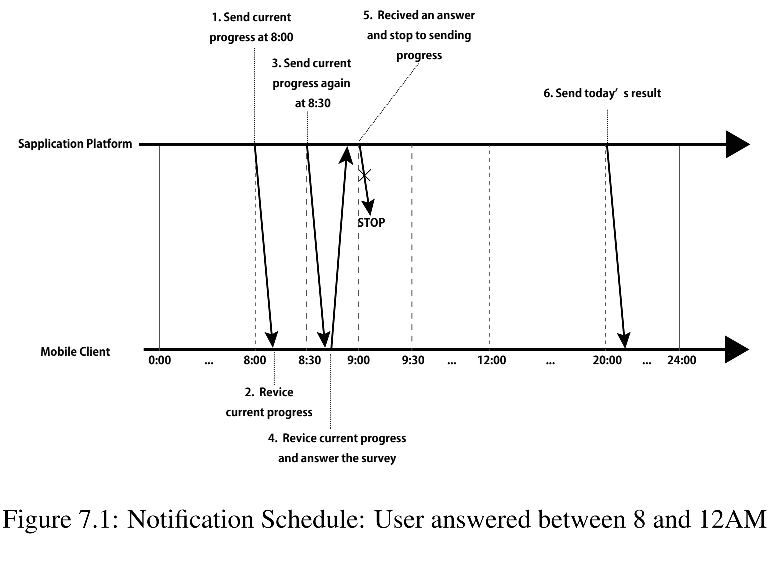

Figure 7.1: Notification Schedule: User answered between 8 and 12AM

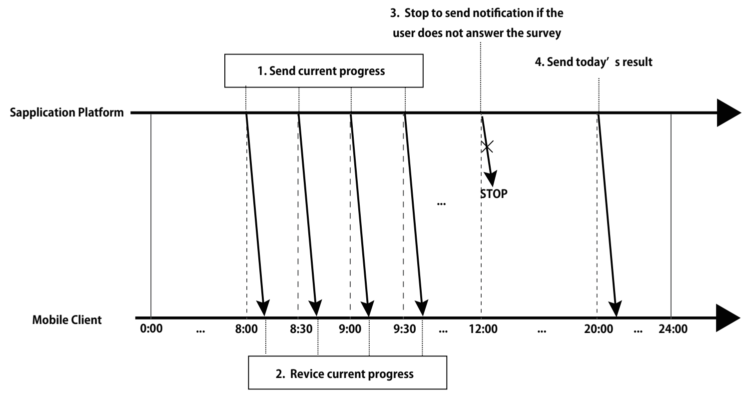

Figure 7.2: Notification Schedule: User unanswered before 12 AM

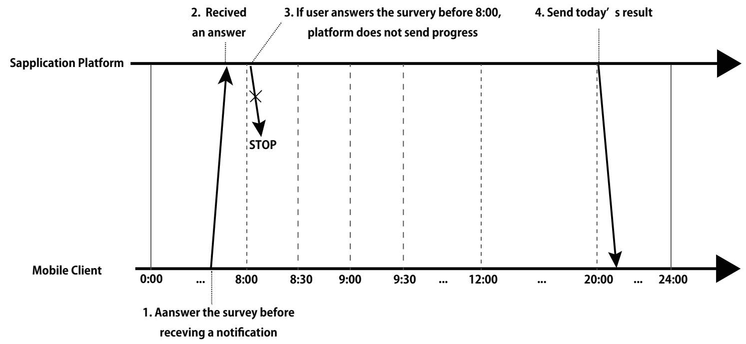

Figure 7.3: Notification Schedule: User answered before 8 AM

7.1.2 Used Information Sharing Models

In the Self–Report Study, *Sapplication platform* shares a progress of participants' answer for self–condition check survey with information sharing models (see Section 4.3.2) by using push notification function on their own mobile phone.

Figure 7.1.2 shows a sample screenshot when the mobile phone has revived a notification from Sapplication Platform. A message in the notification will be changed based on the other members progress on this study. Table 7.1 shows a relationship between information sharing models and actual screenshots of information sharing based on the each model. Self–Report study uses four types of information sharing models: *IND* and *iCL, iCP, iCL+eCP*. *IND* is a based–line model in this study. In the *IND*, Sapplication Platform provides information with only own activity data.

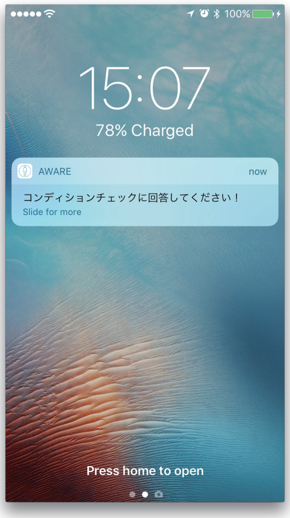

Figure 7.4: Screenshot of notification

Table 7.1: Notification Messages of Result Notification

Models	Notification Message
IND	*"Lets ́ answer the condition check soon!"*
iCL	*"Let's cooperate with the team and set the response rate of the condition check as fast as 100%! Currently Team-X response rate is –%."*
iCP	*"Lets ́ answer condition checks earlier than other team members! Team-Xs' responsiveness is D; unresponsiveness is A and B, C."*
iCL+eCP	*"Let's cooperate with the team and make the response rate of the condition check 100% faster than the opponent team! The response rate is –% for Team-X, –% for Team-Y."*

At 8 PM, Sapplication Platform provides a notification which includes answered time from 8 AM. For example, in the case of that a user answered the survey at 8:24, the notification title is *"Today, you answered the condition check +24 minutes! See you tomorrow."* Meanwhile, *"Today, you answered the condition check -24 minutes. See you tomorrow,"* if the user answered it at 7:36. Table 7.2 shows contents of notifications for **Result Notifications**.

Table 7.2: Notification Messages of Result Notification

Models	Answered	Un-answered
IND	*"Today's result: you answered the condition check +24 minutes! See you tomorrow."*	*"Today's result: you did not answered the condition check! Letsánswer it tomorrow!"*
iCL	*"Today's result: You answered the condition check in + 24 minutes. In addition, the response rate of the team was 50%. See you tomorrow."*	*"Today's result: You have not answered the condition check. In addition, the response rate of the team was 50 %. I look forward to tomorrow."*
iCP	*"Today's result: You answered the condition check at 24 minutes. The ranking in the team is 1st: A. The unresponded people in the team are B and C, D. See you tomorrow."*	*"Today's result: You have not answered the condition check. The ranking in the team is 1st: A. The unresponded people in the team are B and C, D . See you tomorrow."*
iCL+eCP	*"Today's result: You answered the condition check at 24 minutes. The result is Team-X (Total 56 minutes) vs Team-Y (Total 82 minutes), Team-X is the winner here! See you tomorrow."*	*"Today's result: You have not answered the condition check. The result is the victory of Team-Y because Team-X is incomplete. I look forward to tomorrow."*

7.1.3 Team and Model Configuration

Keio University Rugby Football Club (hereinafter referred as the **Rugby Team**) is our target team for Self–Report Study. The rugby team daily collects their physical and mental condition data using ONE TAP SPORTS[4] which is a web–based survey system for sports, and the National Rugby Team in Japan also uses the same system for managing their players' condition. On the system, they are collecting following data by 7–Points Likert Scales: (1) weight information, (2) sleep duration, (3) sleep quality, (4) fatigue level, (5) stress level, (6) water supply, (7) pain of hamstring muscular, (8) lower back of muscle pain, and (9) muscle pain of calf. Moreover, the Rugby Team [5] is the most historical rugby team in Japan, which is known as the first rugby team in Japan (since 1899). In addition, the team is sill one of a strong rugby team in japan has won the college championship tournament in Japan 5 times. The performance of the top level teams is almost same level between other rival teams. Therefore, condition management is important seriously for them to winning their games, and also all of

[4]https://www.one-tap.jp/top
[5]https://www.kurfc.com/

the players are expected that they have strong motivation and interest to manage their condition data.

From the team, our study picked up 21 male members. These members were chosen from the original team members (the rugby team has 124 players originally) who agree to this experiment. All participants are first–year undergraduate students at Keio University. Moreover, all of the participants' primary phone are iOS devices.

The aim of this experiment was to investigate the effect of four types of information sharing models (i.e., *IND* and *iCL*, *iCP*, *iCL+eCP*) for promoting Self–Report Activity. To using all models to all participants, the members are splits five groups comprising four persons each internal teams (A) to (E) for each team, with team members. Each team was assigned one of the information sharing models as shown in Table 7.3.

Table 7.3: Correspondence of Each Internal-Teams and Information Sharing Models

Information Sharing Models	Rugby Team
IND	Rugby-A
iCL	Rugby-B
iCP	Rugby-C
iCL+eCP	Rugby-D & Rugby-E

7.1.4 Dataset

To understand participants activities, mobile client collects shown in Table 7.4.

Table 7.4: Dataset: Collecting activity data from participants' mobile phone in Self–Report Study

Name	Frequency	Quality	Note
ESM (Self–Condition Check)	daily	—	5–Points Likert–Scale
ESM (Review of Notifications)	daily	—	7–Points Likert–Scale
Location (GPS)	3 minutes	250 meter	
Location (WiFi)	3 minutes	—	—
Activity Recognition	3 minutes	—	—
Weather Information	1 hour	—	Data from OpenWea
Battery	1 minutes	—	—
Screen Status	every time	—	Detecting device usage

Figure 7.1.4 shows sample screenshots of ESM page on the mobile client. The ESM screen appeared when the user opens the app automatically. Totally, the ESMs have seventeen questions. The first half (twelve questions) of ESMs are for self–condition checks such as weight and sleep duration (start and end), sleep quality, fatigue–level, stress–level, nutrition, hydration, sore muscles(hamstring, and back, hip, calves.) The second half (five questions) questions for contents of the push notification message. The questions are the same question in Exercise–Study (see Section 6.2).

Figure 7.5: Screenshot of condition check questionnaires and ESMs

7.2 Experiment Procedure

We obtained approval from our university Institutional Review Board (IRB). The IRB approved following:

- Collecting data from mobile phone (e.g., location and device usage, ambient noise, ESM etc) and physical data from wearable devices (e.g., heart-rate and GSR, skin temperature etc)
- Feedback activity data to other team members except for personal information

Figure 7.6 shows an experimental schedule for Self–Report study. On the first day, we hold an explanatory meeting with each teams as shown in Figure 7.7. The used

ESM configuration file is shown on Appendix E.

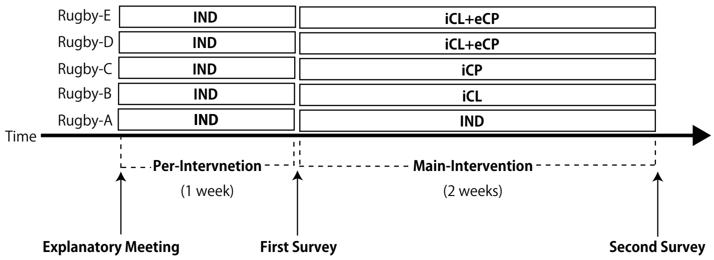

Figure 7.6: Experiment Schedule

Figure 7.7: Explanatory Meeting with Each Team

In the meeting, we described them the overview of study schedule and usage of the Sapplication Platform and mobile client, group configuration. First, all of the participants 1) make own account on Sapplication Platform, and 2) installed the mobile client from AppStore[6]. As a third step, 3) for combining mobile client to Sapplication Platform, participants read a QR code for our study which is made by AWARE Framework. After reading a QR code, the sensing and ESM configurations (see Section 7.1.4) are downloaded and set automatically. Next, 4) we checked "sensing status"

[6]`https://itunes.apple.com/fi/app/aware-client-ios/id1065978412?mt=8`

and "existence of ESMs," "application and privacy setting," "accessibility of remote push notification." Finally, 5) each participant try to answer and upload the condition check as a test themselves.

The study started on the same day for all 22 participants. During the study period, each participant utilized his smartphone. We banned exchanging information related to Sapplication between other teams, and changing settings of the mobile client, sending reminders to coaches during the study. We conducted surveys for all participants about a usage of the system, and measured group–cohesiveness, group–efficacy by using existing methods in the social science community.

The participants answered the questions using a 5–point Likert scale (5: Strongly Agree, 4: Somewhat Agree, 3: Neutral, 2: Somewhat Disagree, 1: Strongly Disagree). The survey comprised the four questions as shown in Table 6.2. The participants had to answer three questions using the 7–point Likert scale. Question 1 (SR-Q1) was, "*How do you feel about activity sharing using the application?*" and Question 2 (SR-Q2) was, "*Do you want to use this application continuously?*". Questions 1 and 2 relate to discomfort with information sharing. Question 3 (SR-Q3) was, "*Do you feel pressure from other members?*" This question relates to pressure from team members.

7.3 Results

In this section, we describe and consider the result of inspection of team performance (TP) and the comfortable level (CL), Team–Efficacy (TE), Team–Cohesion.

7.3.1 Influence on Team Total Performance

This subsection describes and considers the result of TP. As a baseline, Figure 7.8 shows response times during the Pre–Intervention. Figure 7.9 shows response times by each information sharing models during the Main–Intervention. In the figures, the vertical axis signifies response times (minutes) for their condition check from 8 AM and the horizontal axis signifies the each model. Moreover, Table 7.5 is the static of the both figures' response time.

Based on the result above, our analysis shows several significant differences between the information sharing models.

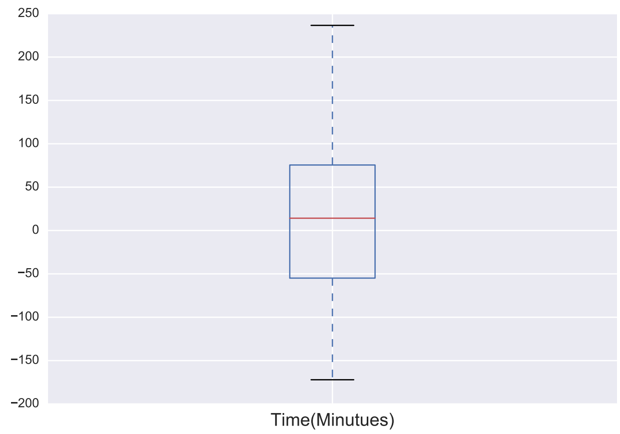

Figure 7.8: Base–Line: Response Times with *IND* in Pre–Intervention

Table 7.5: Statistic of Response Times with Each Interventions

Model	Count	Mean	Std.	Min.	25%	50%	75%	Max.	Response Rate
Pre–*IND*	114	14.84	94.57	-172.1	-54.89	14.19	75.54	236.52	55.55%
Main–*IND*	55	41.28	75.64	-148.89	10.31	52.05	90.11	181.33	78.57%
Main–*iCL*	47	33.32	78.77	-118.43	-29.77	30.25	90.55	209.98	83.93%
Main–*iCP*	24	-3	97.38	-142.96	-103.5	1.9	72.76	138.58	42.86%
Main–*iCL+eCP*	83	19.76	94.11	-182.04	-27.09	9.51	64.78	187.97	74.11%

***IND* as the baseline**

The second column of Table 7.5 means average response time of each information sharing models. From all of the information sharing models and term, a response time during Main–*IND* is the most rate than others (i.e., Pre–*IND*, and Main–*iCL, iCP, iCL+eCP*.)

Compare with the average response time in Pre–Intervention, in the Main–Intervention, only response time of Main–*iCP* is improved 17 minutes. However, other models (i.e., Main–*IND* and Main–*iCL*), Main–iCL+eCP) are decreased. In the addition, a comparison between Main–*IND* and models in Main–Intervention shows that the average response times of all activity shared models (i.e., Main–*iCL and iCP, iCL+eCP*) are faster than Main–*IND*.

The last column in Table 7.5 is the response rate for the condition check. The

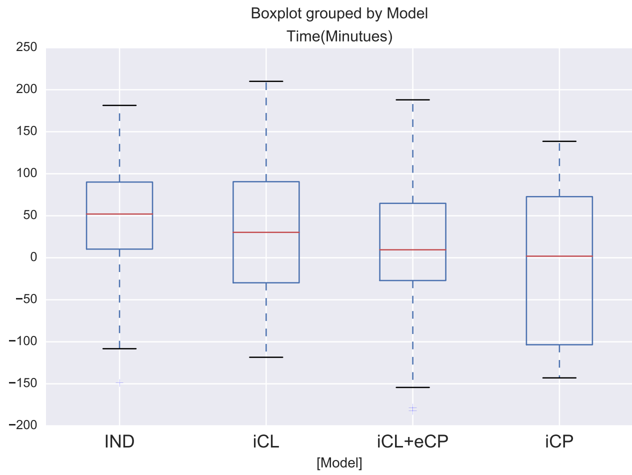

Figure 7.9: Response Times with Each Interventions in Main–Intervention

response rate of Main–*iCP* model has decreased rapidly.

We conducted Analysis of Variance (ANOVA) to prove the significant different between the base–model and proposed information sharing models. In this case, the sample size of response times is deferent between *IND, and iCL, iCP, iCL+eCP*. Thus, we used Welch't t-test for measuring significant different between *IND–iCL* and *iCL–iCL*, *IND–iCP*, *IND–iCL+eCP*. The significant different occurred between *IND–iCP* (p=0.05). Moreover, there is no significant different between *IND–iCL* (p-value=0.61) and *iCL–iCL+eCP* (p-value=0.14).

The Impact of Team Context

In the team, they have their own context. For example, our target rugby team conducts practices Tuesday to Saturday, and also, they have a game on Sunday generally. Monday is a holiday for them. In the addition, their practice (i.e., physical training) start from 6 AM, and the practice is finished around 18 PM. Thought a discussion with coaches in the team, we categories three daily contexts as follows:

Practice Team members have a practice with team members for a day, and they have to go to their field for the practice.

Game Team members have only a game, and all of the members do not have a scheduled practice.

Off Team members do not have a practice and game, and also, they do not need to go to their field.

During the study, there were 10 *practice* days, and 2 *game* days, 2 *off* days. Figure 7.10 shows response times for each team context (i.e., *Practice, and Game, Holiday*) by each information sharing models. Especially, the response time of *iCP* and *off* are faster than other models; the average time is faster -108.6 minutes than *IND* model.

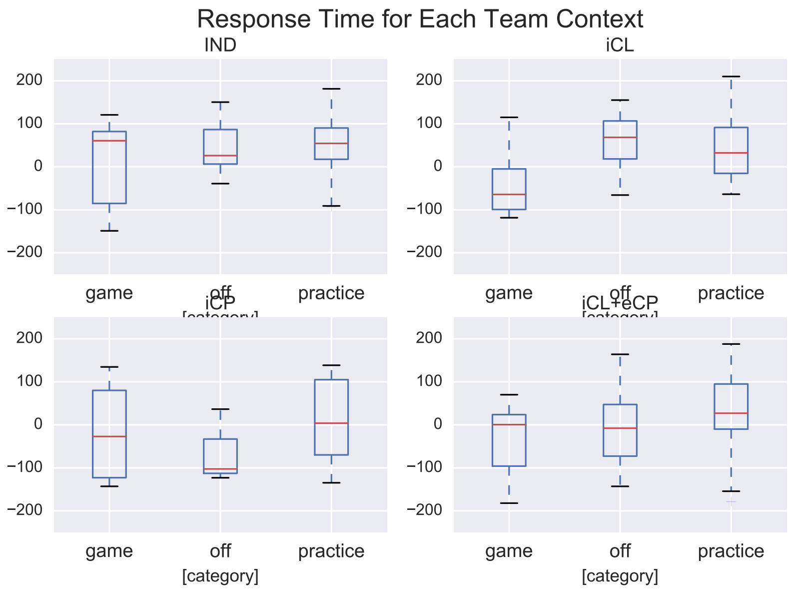

Figure 7.10: Response Time for Each Team Context in *IND and iCL, iCP, iCL+eCP*

7.3.2 Influence on Comfort Level

Table 7.6 and 7.8, 7.7 show questionnaires for a comfortable level.

The SR-Q1 (Table 7.6) measures a comfortable level of the notification message. In the question, the mode value of *Main–iCP and iCL+eCP* are 7 which means that contents of notification are comfortable than other information sharing models. The SR-Q2 (Table 7.7) measures a pressure from team members via the notification messages. As same as SR-Q1, the value of *Main–iCP and iCL+eCP* are 7, and an average of answers higher than others. The SR-Q3 shows the continuation of used notification contents. As shown in 7.8, Mode value of Main–*iCP* and *iCL+eCP* are 7, and an average is higher than other models.

Table 7.6: SR-1: Comfortable Level of Notification Contents
"How do you feel the contents of notification?"

Models	1	2	3	4	5	6	7	NA	Average	Mode	Parameter
Pre–*IND*	3	7	32	19	0	5	21	34	4.21	3	121
Main–*IND*	2	5	20	6	1	6	6	7	3.89	3	53
Main–*iCL*	0	1	16	8	0	0	10	17	4.34	3	52
Main–*iCP*	0	0	9	1	0	1	12	4	5.26	7	27
Main–*iCL+eCP*	1	3	20	8	0	0	27	26	4.88	7	85

Table 7.7: SQ-R2: Social Pressure from Notification Contents
"How do you feel other members' pressure from the notification contents?"

Models	1	2	3	4	5	6	7	NA	Average	Mode	Parameter
Pre–*IND*	1	1	34	8	2	8	23	36	4.62	3	113
Main–*IND*	1	0	25	3	0	7	9	9	4.29	3	54
Main–*iCL*	0	1	18	8	0	0	9	15	4.2	3	51
Main–*iCP*	0	1	8	0	0	1	12	4	5.27	7	26
Main–*iCL+eCP*	2	5	22	3	1	2	29	23	4.84	7	87

Table 7.8: SR-Q3: Continuation of Notification Contents
"How much do you want to use the notification contents continually?"

Models	1	2	3	4	5	6	7	NA	Average	Mode	Parameter
Pre–*IND*	1	8	34	8	1	5	22	33	4.30	3	112
Main–*IND*	0	5	24	2	2	6	7	7	4.02	3	53
Main–*iCL*	0	0	19	7	0	0	10	15	4.31	3	51
Main–*iCP*	0	0	9	1	0	1	12	3	5.26	7	26
Main–*iCL+eCP*	0	6	23	3	1	0	31	22	4.92	7	86

7.3.3 Group Efficacy and Cohesiveness

This section describes the result of termly survey which surveys are conducted at beginning of Main–Intervention and end of Main–Intervention.

Table 7.9 shows a value of Group–Efficacy and –Cohesiveness value between before and after Main–Intervention by each team. The average value of *Group–Efficacy* on *iCL+eCP* and *iCP* is increased after using the information sharing model. In the addition, on *iCP*, the value of Cohesiveness level is increased after using the model.

Table 7.9: Group Efficacy and Cohesiveness

	Average of Group Efficacy			Average of Group Cohesiveness		
	Before	After	Gap	Before	After	Gap
IND	45.8	43	-2.8	70.6	64.6	-6
iCL	60	53.75	-6.25	88.5	84.75	-3.75
iCP	52	53	1	87.5	79.75	-7.75
iCL+eCP	47.38	54.13	6.763	74.25	78.25	4

7.3.4 Collected Activity Data

For understanding participants activities, mobile client collects following data in Table 7.4.

Table 7.10: Dataset: Amount of collected activity data from participants' mobile phone

Sensor Name	Records
Location (GPS)	15650
Location (WiFi)	4993
Activity Recognition	142602
Weather Information	693
Battery	17288
Screen Status	7552

Figure 7.11 to 7.16 shows an amount of each collected sensor data. A row in vertical axis means each participant, and a column in horizon axis is a day during main–study. A cell visualizes an amount of the record by the day and participant, and also, a thick color of the cell has lots of records by other cells.

From the history of application usage and a questionnaire about device usage at end of the study, 7 participants complained that the battery drains fast. Due to the battery consumption, during the study, 5 participants (i.e., *P1, P11, P14, P15, and P21*) used *Low Power Mode* which is iOS official low battery consumption mode. On the same reason, 5 participants turned off location sensors (i.e., *P4, P11, P13, P14, and P21*) and denied to use background refresh (i.e., *P11*). Nevertheless, they got an attention to application setting at beginning of the study.

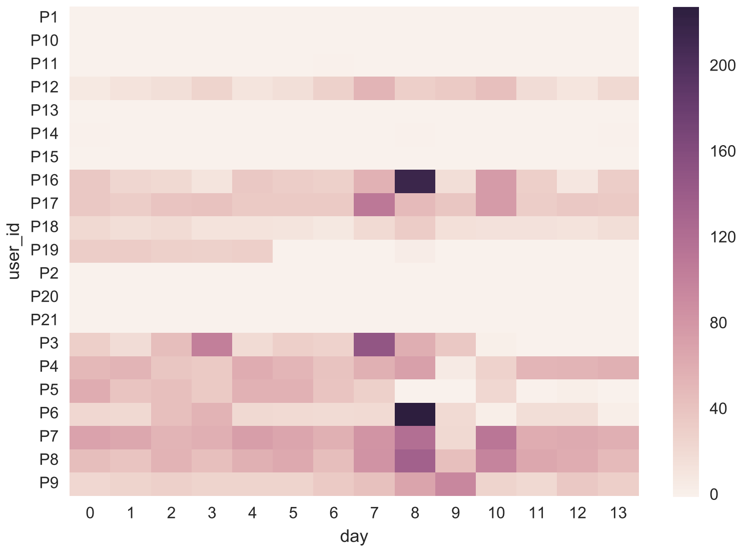

Figure 7.11: Amount of Location Events

7.3.5 Interview to Team Manager

This section shows results of interviews to a manager who is a head coach of S&C in the team. In the interview, we inquired above questions:

I1 **Beneficial Influence:** *How do you think beneficial influences for the team–level self–report activity by using Sapplication Platform?*

I2 **Harmful Influence:** *How do you think Harmful influences for the team–level self–report activity by using Sapplication Platform?*

I3 **Expectations:** *What kind of expectations did you have about using the Sapplication Platform through this experiment?*

During the interview, both an interviewer and an interviewee could see the same figures (Figure 7.9 and 7.10) and tables (Table 7.6, 7.7, 7.8, and 7.9) related to the result of this experiment.

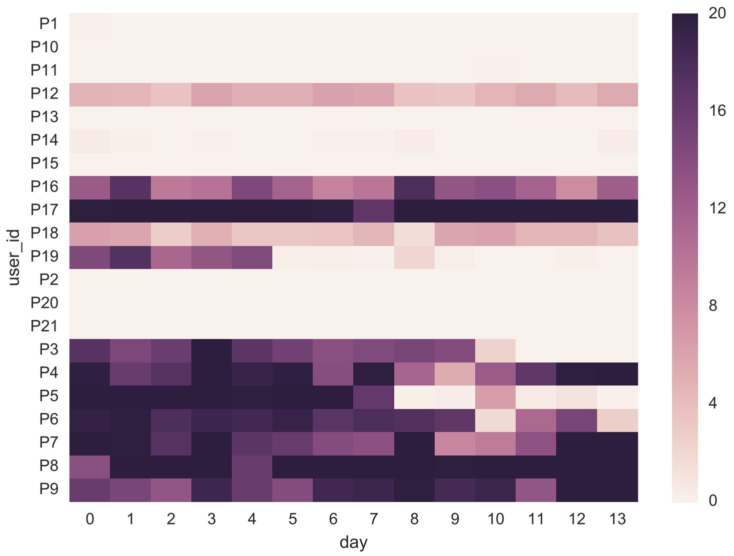

Figure 7.12: Amount of WiFi Access Points Data

I1: Beneficial Influence

The head coach felt the average response speed is enough to change the training menu based on the result of conditioning check for preventing injuries of players. He expressed as follows:

> *"Moreover, since average response time of condition check is answered within one hour in most models. Therefore, the response time is enough and also the data can be reflected on team practice quickly. For example, based on the data, we can change a training menu data for preventing injury if the player has extreme fatigue."*

Moreover, the same head coach expressed that "effective use of Human Resource," and "numeration of team–level intervention" are a beneficial influence for preventing players' injuries and team operations of Sapplication platform as follows:

> *"In past systems (i.e., ONE TAP SPORTS), the reminders were sent by staffs, but by converting the task to an automation by machine, the staffs*

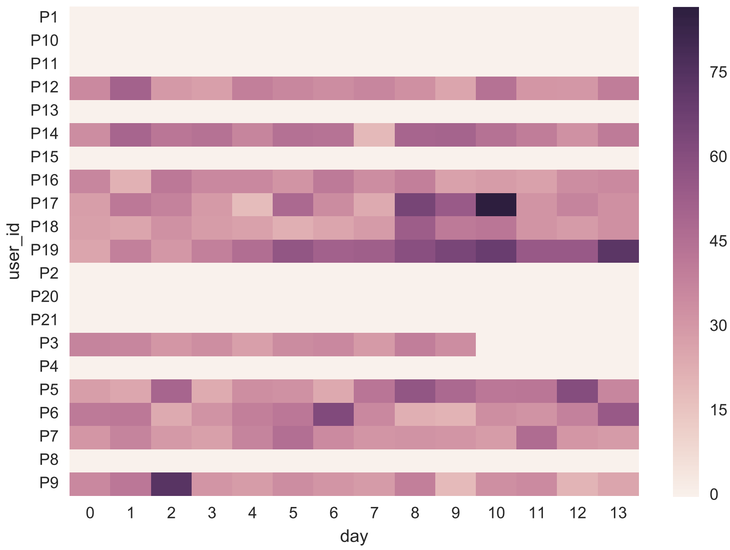

Figure 7.13: Amount of Activity Events

> *can utilize the excess time for doing other tasks such as preparation for nutrition supply, massage, taping for players. In terms of effectively utilizing human resources, the platform contributes to the prevention of athletes' injuries and the efficiency of condition management."*

In addition, he strongly interested into use the platform by themselves, and use their daily operation.

> *"The response time and rate are changed just by visualizing the progress of response of the conditioning check is very interesting possibility phenomenon. We want to use the system in our team management and change parameters by ourselves for promoting members' behavior. I feel that the different depending on the context of the team (practice, game, and holiday) is also interesting phenomenon."*

I2: Harmful Influence

About a harmful influence, the head coach expresses response rate is not enough for using the platform. In the models which are used in this self–report study (*IND, iCL,*

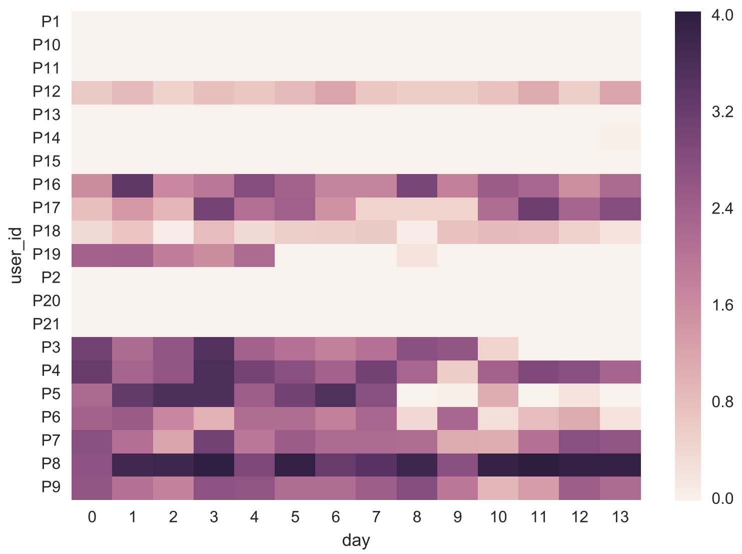

Figure 7.14: Amount of Weather Data

iCP, and iCL+eCP), he wants to use the *CL* which is a high response–rate model.

> *" On the other hand, the response rate is a problem to be solved. The ideal percentage is 100% for managing the team condition. However, the response rate is around 70-80%. In the current case, I'm thinking to use iCL, but I'm also interested in using iCP+eCP for its effectiveness of comfortable level, team–cohesivenss, and team–cohesiveness. "*

I3: Expectations

The coach expressed an expectation that using other data has a potential to promoting other sub–goals. For example, sharing weight training data or running data (from wearable sensor) has a huge potential for promoting quality of physical training.

> *"Our team is collecting GPS data in the game/practice using wearable sensors. Also, we are recording training data like a maximum weight of training. I am interested in using these data in the platform for promoting members' behavior."*

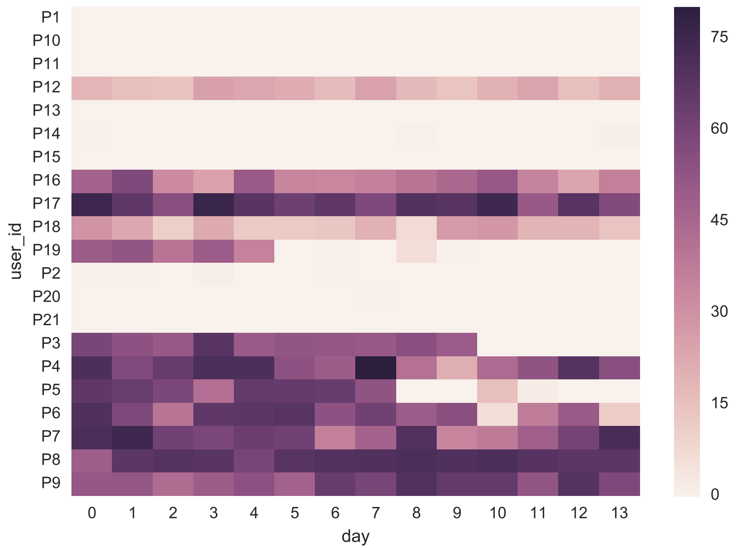

Figure 7.15: Amount of Battery Level

7.4 Discussion

This section describes discussion of the self–report study.

7.4.1 Long–Term Behavior Change

This experiment conducts 3–week study (1–week pre–study and 2–weeks main–study) for measuring an effect of short–time behavior change by using information sharing models on a sports team. However, constructing general team–level behavior change model is required a more large number of experiment and samples (i.e., age and gender, personality, culture.) For example, Lin el al., [8] they are during 2 months which included 2 weeks pre–study and 4 weeks main–study, 2 weeks post–study, for evaluating long–term behavior change. In the Social fMRI [12] had 3 months study. As an example of large scale research, Schneidera [86] recruited 1236 participants for their research by using a Social Network Service.

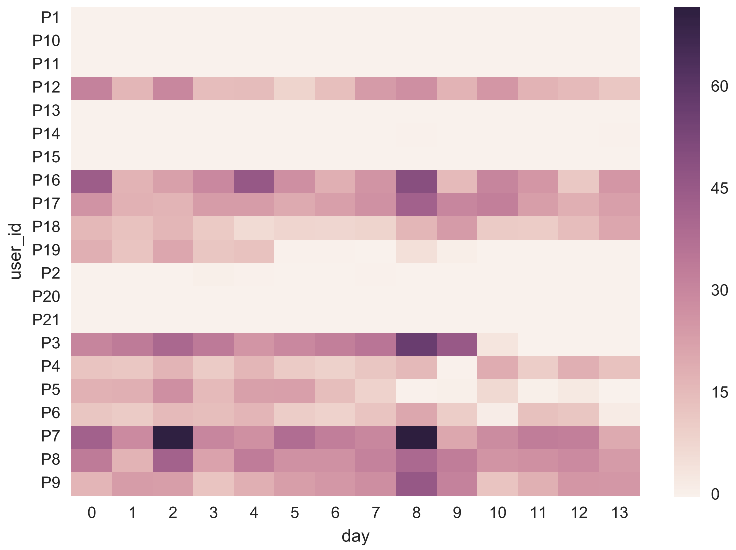

Figure 7.16: Amount of Screen Events

7.4.2 Personality

In this experiment, we used a push–notification–based information sharing method which allows sharing other members progress passively. As an evaluation, the notification counts and schedules were delivered with a fixed schedule regularly. However, from the result of survey, participants felt the notification is a lot. Okoshi et al., [87] proposed a breakpoint based notification providing method. By using the method, access rate of the provided information has been improved. In this sense, controlling the notification timing could be one of the important factor for enhancing team–level behavior change in addition to the quality of content.

7.5 Summary

In this section, we described an experiment (namely **Self–Report Study**) for measuring influence on information sharing (i.e., *IND, iCL, iCP,* and *iCL+eCP*) for team–level self–report activity behavior change with a rugby team in a university. In this study, the *Sapplication Platform* shares the progress of response for their condition check among team members, and we also analyzed the effect of the information sharing models. The key contents of this section are below:

- **Self–Report Study** is an experiment for measuring influence with push notification based information sharing with four types (i.e., *IND and iCL, iCP, iCL+eCP*) of information sharing model.
- The study has Pre-Intervention (1 week) and Main-Intervention (2 weeks) term, and I evaluate the effects of interventions from TP and CL, TE, TC.
- The result shows that *iCP* model shortens team total response time from Pre–*IND* and Main–*IND*, and competition elements (i.e., *iCP* and *iCL+eCP*) is an effect of promote Team–Efficacy and Team–Cohesiveness.
- Finally, we describe limitation of the Self–Report Study and future works: long–term behavior change and personalization, battery consumption.

Chapter 8

Conclusion

This chapter describes a conclusion of team–level behavior change research. First, Section 8.1 shows applications of Sapplication Platform. Second, Section 8.2 shows future works of team–level behavior change. Finally, Section 8.3 summarizes the concluding remarks of this thesis.

8.1 Application of Team–level Behavior Change

The concept of *Sapplication Platform* and TBC–Cycle have potentials to apply diverse research areas. As examples of the feasible application by fruits of this dissertation, this section shows the capability of evidence–based team–level intervention and analytics in Section 8.1.1, and extensibility of TBC-Cycle to other types of teams in Section 8.1.2.

8.1.1 Evidence Based Team-level Intervention Studies for Non–programmer

Sapplication Platform provides information sharing method and an environment of evidence–based analytics for non–computer programmer (e.g., psychologist, medical doctor, and coaches in a sports team.) In the other word, they can conduct an evidence–based team–level intervention study without programming on Sapplication Platform, by just setting participants, information sharing models, data, and term. Figure 8.1 shows a map which contains geographical location (e.g., around practice field of the rugby team) and physical activity data (e.g., still, walking, running, biking and automotive condition which are provided by API on smartphone) when they answer an ESM, as an example of visualization of collected data using the platform. They can quickly understand where the ESM is answered in what condition, and measure the effects of information sharing.

The functions can apply to various types of group–level intervention researches. The example cases in a sports team are as following:

- Enhancing distance of running and maximum speed using information sharing between teams (i.e. rival teams) in a league
- Empowering training effects (e.g., maximum weight of wight–training, quality of skill training, and number of training) using information sharing between categories (e.g., position, grade, and) in a team
- Modifying sleep environment (e.g., ambient noize, temperature, and humidity) for improving quality of physical recovery using information sharing in a team

8.1.2 Applicability of TBC-Cycle to Other Types of Teams

As the first trial, this thesis focused on enhancing team-level behavior in sports teams which played a team game (e.g., baseball and rugby team) in a university. Addition-

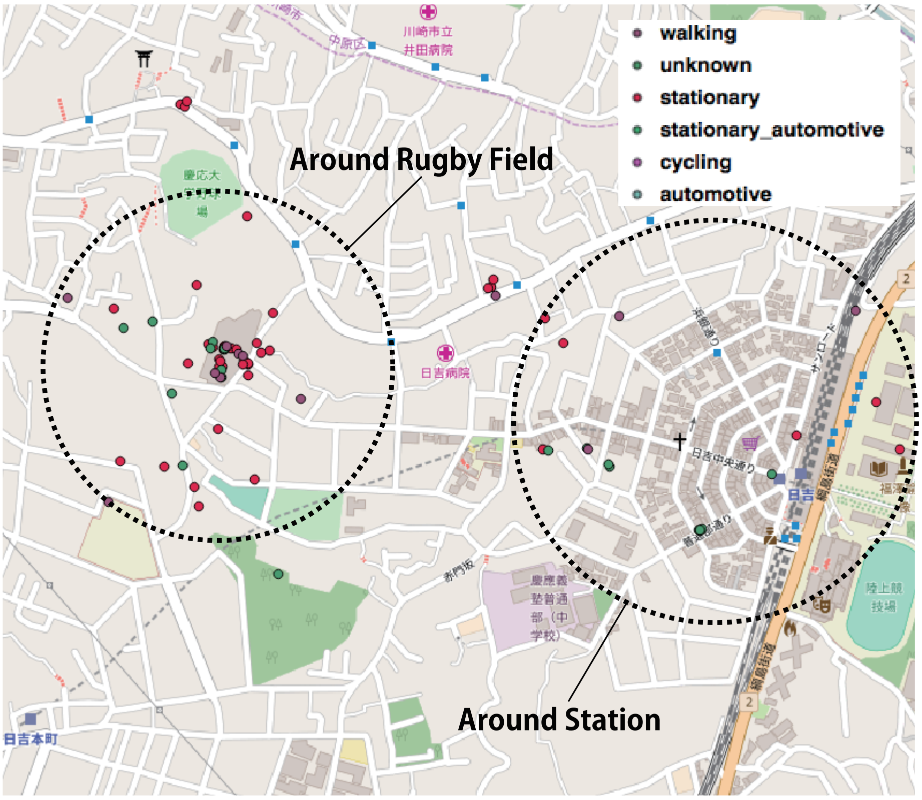

Figure 8.1: Response Map with Activity Type

ally, team members in the team has a strong motivation to achieving their final team goal such as "*winning a collage championship.*" The result for the teams shows the team–based competition model (e.g., *iCL+eCP*) has potential to use other competitive sports teams what has played team games examples: football, soccer, and hockey. On the other hand, in the real world, there are various types of the organized groups such as project team in a company, a circle in a university, and the neighborhood association, other than the sports team. The effectiveness of information sharing for enhancing team–level behavior change in the all teams is not substantiated by only this dissertation's evaluation. So that *Sapplication Platform* was designed to use the various team, the effectiveness of information sharing models in other types of teams will be tackled on the platform in the future works.

8.2 Future Works on Team–level Behavior Change

This section presents avenues for future work on *Sapplication Platform* and team–level behavior change research.

First, section 8.2.1 describes a future large–scale and long–term study for archiving the final goal that to constructing a team–level behavior change model. Second, section 8.2.2 explains potentials of personalized information sharing. Third, section 8.2.3 shows a potential of TPI (Team Performance Indicator) prior team–level intervention using reverse *TBC-Cycle*. Next, section 8.2.4 mentions research opportunities for enhancing team–level behavior change by applying other activity data. Finally, section 8.2.5 states a necessity of preventing misuses and privacy concern on Sapplication Platform and TBC-Cycle.

8.2.1 Large–scale and Long–term Studies

First, an ultimate goal of team–level behavior change research is "constructing a general team–level behavior change model." Our studies' scale and term in this dissertation are 64 and 21 participants who belonged sports team in a university, and three weeks studies respectively. Therefore, the results of this dissertation yet address the short–term behavior change. In order to achieve the goal, **long–term** and **large–scale** studies are an essential task. Originally, TTM [35], which is a well–known method to comprehend level of individual behavior change, decides the long–term behavior change is completed if a user still doing the target activity over six months; more than six–months study is one of a criterion of long–term evaluation.

Besides, a wide variety of users and teams are there in the actual use case. To investigate effectiveness among user characteristics, including age, gender, and culture, is a future work. In the same reason, a difference in a team is an essential factor of team–level behavior change research. For example, comparing the effectiveness of information sharing models between *Independent–teams* (e.g., Field&Track, Swimming, and Archery team) and *Interdependent–teams* (e.g., Baseball, Rugby, and Football) is yet another challenge. Logically, a working team in a company, a project team in a research laboratory, and a group in a neighborhood association are future research subjects.

Due to the long–term studies, teams will take various context (e.g., *long vacation*, *training camp*, and *test season in sports team*) in addition to three context in this dissertation (i.e., *Practice*, *Game*, and *Off*). Analyzing reason of the effectiveness of information sharing models in each the contexts are future research tasks.

Further, automated analytics and feedback for managers are a future development task that improves user experiences among the platform usage in the real environment.

8.2.2 Personalized Information Sharing

This dissertation analyzed the effectiveness of "contents" on information sharing. The results of studies show that sharing information enhanced the team members' activities. In this sense, on the information sharing in the team, the "contents" of information assume that is a significant factor for team–level behavior change. In addition to the "contents," the effectiveness might be related to other triggers such as "timing," "location," and "team context(e.g., *off, practice, and game day*)." The triggers are future research area of the team–level behavior change research.

Personalizing sharing contents is a general solution to improve user satisfaction, which is used in the practical systems such as recommendation systems on electronic commerce's web–site. In the same way, the solution is expected that a practical method for improving user satisfaction and effectiveness of behavior change. In Gamification, Richard [88] categorized four player types (i.e., Achievers, Explorers, Socializers, and Killers) from system usage data as shown in Figure 8.2, and the research showed play–style and player's incentive are different by each player's player category. Analysis of the use types and personalizing the sharing contents are future challenges. In addition, sharing different information in a team due to simple personalization may make discord among them members. For example, in order to adjust personalization, if the Sapplication Platform shares data to A using *iCL* and B by *iCP*, only B (*iCP*) can check the other member performance. In this sense, adjusting team–based intervention methods is required, and it is a future work.

Not only contents of information but also information providing timing assumes that also enhance behavior change. For reducing users' perceived mental effort, Okoshi et al. [87] controlled notification timing based on the breakpoint which is detected from mobile device usage. Moreover, Obuchi et al. [89] investigated an incorruptibility of physical activity–based breakpoints using activity recognition API on a smartphone. Their result shows breakpoint-based notification delivery improve 70.0% user's response time, when user's activity was changed from "walking" to "stationary" after the notifications were observed, in the best case. In this thesis, Sapplication Platform

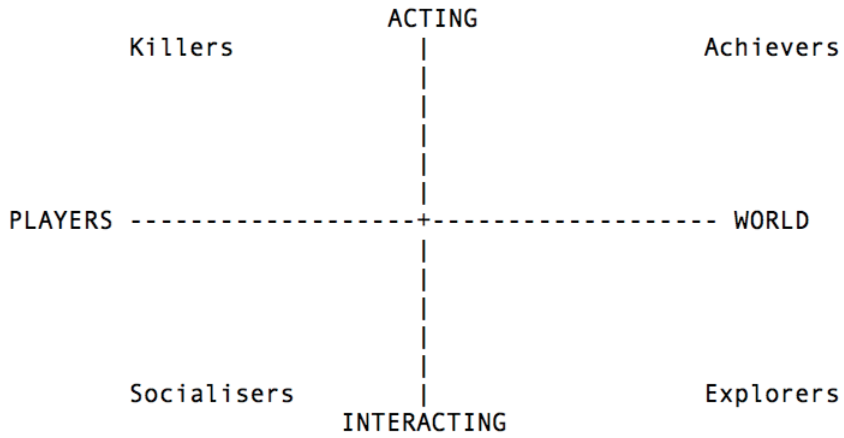

Figure 8.2: Bartle Taxonomy of Player Types [88]

provides information regularly (i.e., providing information via push notification on a smartphone every 30 minutes from 8 AM to 12 AM) in order to fix a number of providing information sharing opportunities. Adjusting occasion of information sharing for improving a quality of data provision is yet another future work.

Using *fake information* is a suggestive research area for behavior change research. For example, Placebo Effect [90, 91] is one of a well–known phenomenon in the medical field, and was applied another research field such as promoting sports performance [92]. Placebo Effect means that even if prescribing a placebo, some improvement is seen by believing that the placebo is real medicine. In the Ubicomp community, Nakamura et al. [93] provided controlled heart–rate which is generated by based on their proposed models. In this sense, fake information assumes that has a potential to enhance human behavior powerfully. Analyzing the effectiveness of *fake information* in team–level behavior change is yet another future work.

8.2.3 TPI Prior Team-level Intervention by Reverse *TBC-Cycle*

In this dissertation, TBC-Cycle, as shown in Figure 4.3, was used by clockwise rotation for evaluating the effects of information sharing models. Through the long–term and large–scale evaluation above, Big Data (i.e., lifelog data from team members) will be stored. By using the Big Data, Sapplication Platform can estimate a team–level intervention method (i.e., lifelog–data, information sharing models, and team) which is the most efficient for enhancing team–level behavior. *Reverse TBC-Cycle* is a concept to applying the estimated method to team–level behavior change.

A dashed line in Figure 8.3 shows a concept of (*Reverse TBC–Cycle*). On the cycle, first, team manager decides a specific parameter on Team Performance Indicator (TPI) for a sub–goal on Sapplication platform. Second, Sapplication Platform estimates a team-level intervention method (e.g., kind of information sharing, lifelog data, group) for achieving the selected TPI based on the Big Data (i.e., intervention results of other teams). Finally, Sapplication Platform shares information using the suggested intervention method, and team members will make an effort to achieve their sub–goal. To establishing an effectiveness of the *reverse TBC–Cycle* is yet another future work.

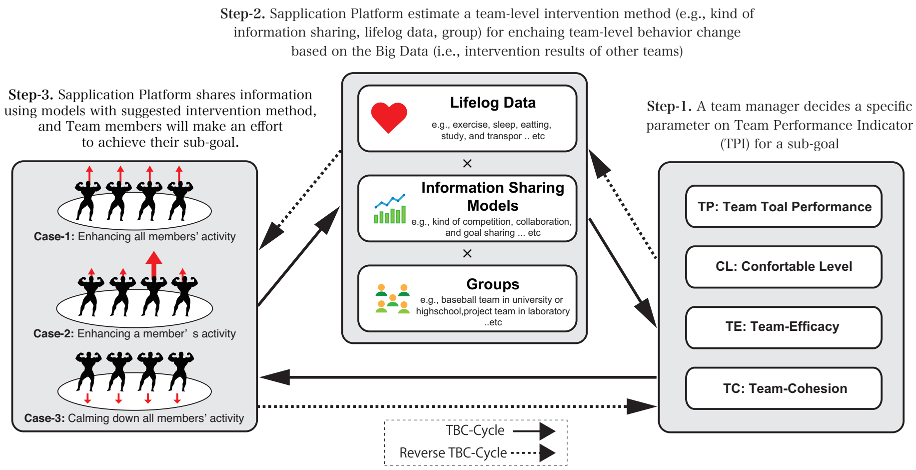

Figure 8.3: Reverse TBC–Cycle

8.2.4 Applying Multimodal Lifelog Data for Enhancing Team–Level Behavior Change

The studies on this dissertation applied the information sharing models for enhancing exercise activity by sharing a number of exercises, and for promoting self-report activity by sharing response time of the report. However, the number of collectible lifelog data is expanding rapidly, and valuable data is still buried in their personal space. In the other word, the buried data still has infinite potential to enhance team-level behavior change. Current *Sapplication Platform* can share data that has stored in the connected AWARE database. On the platform, countable data such as daily steps, calorie consumption, and moving distance are examples of the usable data in the database.

In addition to the current function, an implementation of Application Program Interface (API) for importing other platforms' data (sleep duration from Fitbit API) is powerful functions for more flexible team–level intervention study on *Sapplication Platform*. For example, Existing lifelog applications are providing API (e.g., Fitbit [1], Moves [2], and MicrosoftHealth [3] API) so that, various types of data can be accessed via the APIs. Besides, more variety of lifelog–data will be collected due to the evolution of mobile/wearable sensing technologies.

In addition, managing the *Sapplication Platform* as an open source software (OSS) is one of the solutions to use the platform widely variety researchers, and supporting multiple lifelog data openly. As a role model, AWARE [69] and Sensus [71] manage their mobile clients and servers as an OSS, and extending their platform contentiously.

8.2.5 Preventing Misuses and Privacy Protection

The team-level behavior change cycle and systems have a possibility to lead people to an antisocial behavior like a mind control. For preventing the misuses, additional studies must be required.

Moreover, a privacy observance is an important factor in the real environment. In this dissertation, Sapplication Platform collected all collectible lifelog data (e.g., location, smartphone usage, and physical activity). When a user registers for the Sapplication Platform, team members approve data access. Therefore, team managers (coaches, trainer, and researchers) can be accessed the data. However, extending TBC-Cycle and Sapplication Platform to other groups (such as circle, community, and organization) need to design data management policy. As an example of the policy, the lifelog data is stored in the user's database every day, and if the platform needs to use the data, the platform sends an access request to each user. The platform can access to the database after the user accepts the request, and the user is possible to change the data accessibility after the approval.

8.3 Concluding Remarks

The rapid spread of smartphones and wearable devices has significantly been enabling activity sensing technologies, and it enables that most people who have the devices, to

[1] `https://dev.fitbit.com/jp`
[2] `https://dev.moves-app.com/`
[3] `https://developer.microsoftband.com/cloudAPI`

collect various type of activities in their daily lives as lifelog data conveniently. In the ubiquitous computing environment, the collected data is used for promoting a human behavior in any cases such as exercise, eating, and sleeping, as a use–case. In addition to the environment, in a general human life–style, the majority of people are spending their most of time in organized groups (e.g., sports team, class in a school, and project team in a company.) including on-line and off-line with their devices.

To the best of our knowledge, existing behavior–change researches mainly focused on individual or group level behavior change by using the mobile/wearable devices and collected data. Moreover, traditional approaches in Social Psychobiology tackles to analyze group– and team–level behavior just by observation without dynamic intervention using information technologies. However, most people spend in organized groups surrounded by ubicomp environment in near future, so that methodologies for empowering the team–level activity and evaluation method of effectiveness are significant research subject of practical information management in the organized group in the ubicomp era.

This dissertation studied the impact of information sharing on the team–level behavior change in the ubiquitous environment for the first time. For enhancing and measuring team–level behavior change, we proposed "Team–level Behavior Change Cycle (TBC-Cycle)" which is generated from existing approaches of individual–level behavior change using information technologies. "Sapplication Platform" is a platform for no–programing skill researchers/team–managers to apply the TBC-Cycle to real–teams, which manages "team members," "schedule/kinds of intervention methods (i.e., information sharing models)," and "evidence data during the interventions." As an intervention method for a team, *Sapplication Platform* can share lifelog data via six types of information sharing models (e.g., *IND, iCL, iCP, iCLCP, iCL+eCP, and iCLCP+eCP*) which are based on the- "competition" and "collaboration." To evaluate the impact of the information sharing models in teams, in this dissertation, we conduct two extend extended studies using "Sapplication Platform" over a period of six weeks with baseball–(empowering exercise activity) and rugby–(enhancing self–report activity) team in the university. Through the evaluations, our analysis showed that lifelog data are closely related to the team's original performance indicator effectively enhance team behavior change. Further, use of the "team–based competition" concept model (*iCL+eCP*) was most effective for teams in a competitive situation, such as sport teams, among the proposed models.

This dissertation has the following contributions:

- As an attractive new interdisciplinary research, **team-level behavior change research**, using information sharing among team members in Ubicomp environment, has created in this dissertation.
- To enhancing team-level behavior change, we established **TBC-Cycle** to utilize buried data and proposed six-types of information sharing models (*IND, iCL, iCP, iCLCP, iCL+eCP, iCLCP+eCP*), that can be used as team-level interventions on the cycle, based on Competition and Collaboration techniques.
- In addition, through team-level intervention studies using the proposed information sharing models in the real teams are revealed that competition between teams (*iCL+eCP*) promotes team behavior change in the sports team that performs targeted competitive team sports.
- For end users, we implemented *Sapplication Platform*, which can easily conduct an evidence-based team-level intervention research using the proposed six types of information sharing models and TBC-Cycle.

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Appendix A

The Japanese Collective Efficacy Questionnaire for Sports: JCEQS (Japanese)

日本版スポーツ集団効力感尺度

(the Japanese Collective Efficacy Questionnaire for Sports: JCEQS)

● それぞれの質問に対して，**次に行われる試合（直近の試合・大会など）**において，**あなたが所属しているチーム（集団）が「できる自信の程度」**はどれぐらいだと思っていますか？　0〜10 の中からもっとも当てはまる数字に○をつけてください．

	まったく自信がない					どちらでもない					非常に自信がある
1.　われわれのチームは，能力を発揮できる．	0	1	2	3	4	5	6	7	8	9	10
2.　われわれのチームは，チームに起こる様々な障害を乗り越えることができる．	0	1	2	3	4	5	6	7	8	9	10
3.　われわれのチームは，相手チームよりも良いプレイができる．	0	1	2	3	4	5	6	7	8	9	10
4.　われわれのチームは，問題を解決できる．	0	1	2	3	4	5	6	7	8	9	10
5.　われわれのチームは，常に前向きでいることができる．	0	1	2	3	4	5	6	7	8	9	10
6.　われわれのチームは，良い作戦を立てることができる．	0	1	2	3	4	5	6	7	8	9	10
7.　われわれのチームは，プレッシャーがあってもいつも通りプレイできる．	0	1	2	3	4	5	6	7	8	9	10
8.　われわれのチームは，努力を惜しまずプレイできる．	0	1	2	3	4	5	6	7	8	9	10
9.　われわれのチームは，ベストメンバーでなくても良いプレイができる．	0	1	2	3	4	5	6	7	8	9	10
10.　われわれのチームは，いつもコミュニケーションを十分に取ることができる．	0	1	2	3	4	5	6	7	8	9	10

Figure A.1: The Japanese Collective Efficacy Questionnaire for Sports (Source [50])

Appendix B

An Instrument of Measure Cohesiveness in Sport Team (Japanese)

Table B.1: An Instrument of Measure Cohesiveness in Sport Team (Source: [38])

Subscales	#	Question
メンバへの親密さ	1.	チームに対して友情を感じ、それに満足している。
	2.	チーム内でもめごとがたくさんあり、お互いにうまくやうていけない。
	3.	チーム内は親密であると思う。
	4.	チーム活動以外でも、メンバーはお互いにうまくやっていける。
	5.	メンバー間の人間関係、良いと思う。
	6.	チームメンバーはお互いに強い仲間意識をもっている。
	7.	チーム内の人間関係が好きである。
チームワーク	8.	チームメンバー間のコミュニケーションは少ない。
	9.	試合で負けていても、チームはしっかりとまとまつている。
	10.	自分のチームは、試合ではすばらい、チームワークを発揮する。
	11.	メンバーは皆チーム内での自分の役割を自覚している。
魅力	12.	勝つためにまとまることのできるチームであると思う。
	13.	あなたの役割やチームへの貢献はメンバーから十分に認められている。
価値の認められた役割	14.	あなたの役割やチームへの貢献はコーチングスタッフから十分に認められている。
	15.	今のチームのメンバーであることには非常に価値がある。
目標への準備	16.	今のメンバーであることに大変誇りを感じている。
	17.	チームの指導方法は良いと考えている。
	18.	試合で必要な作戦、役割、手続きは、コーチから十分に与えられていると思う。
	19.	コーチの作戦が理解され、達成されるまで、十分に訓練されていると思う。
規範	20.	練習をさぼることは許されるべきではないと思う。
	21.	練習を少しぐらいさぼるのはしょうがないし、許されると思う。

Appendix C

Questionnaires about Team–Efficacy Level in Japanese

Table C.1: Questionnaires about Team–Efficacy Level in Japanese

#	Question
TE-1	われわれのチームは、能力を発揮できる。
TE-2	われわれのチームは、チームに起こる様々な障害を乗り越えることができる。
TE-3	われわれのチームは、他のチームよりも [—] できる。
TE-4	われわれのチームは、問題を解決できる。
TE-5	われわれのチームは、常に前向きでいることができる。
TE-6	われわれのチームは、良い作戦を立てることができる。
TE-7	われわれのチームは、プレッシャーがあってもいつも通り [—] できる。
TE-8	われわれのチームは、努力を惜しまず [—] できる。
TE-9	われわれのチームは、ベストな環境でなくても [—] ができる。
TE-10	われわれのチームは、いつものコミュニケーションを十分に取ることができる。

Appendix D

Questionnaires about Team–Cohesion Level in Japanese

Table D.1: Questionnaires about Team–Cohesion Level in Japanese

#	Question
TC-1	チームに対して友情を感じ、それに満足している。
TC-2	チーム内にもめごとがたくさんあり、お互いにうまくやっていけない。
TC-3	チーム内は親密であると思う。
TC-4	チーム活動以外でも、メンバーはお互いにうまくやっている。
TC-5	メンバー間の人間関係は、良いと思う。
TC-6	チームメンバーはお互いに強い仲間意識をもっている。
TC-7	チーム内の人間関係が好きである。
TC-8	チームメンバー間のコミュニケーションは少ない。
TC-9	[—] の状態が悪くても、チームはしっかりまとまっている。
TC-10	自分のチームは、[—] のために、すばらしいチームワークを発揮する。
TC-11	メンバーは皆チーム内で自分の役割を自覚している。
TC-12	[—] ためにまとまることができるチームであると思う。
TC-13	あなたの役割やチームへの貢献はメンバーから十分に認められている。
TC-14	あなたの役割やチームへの貢献はコーチングスタッフから十分に認められている。
TC-15	今のチームメンバーであることに非常に価値がある。
TC-16	今のチームのメンバーであることに大変誇りを感じている。
TC-17	[—] のフィードバック方法は良いと考えている。
TC-18	[—] のために必要な情報をシステムから十分に与えられている。
TC-19	[—] が十分に理解され、[—] のために、十分に訓練されていると思う。

Appendix E

ESM Configuration file for iOS ESM


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