Usability and Motivational Effects of a Gamified Exercise and Fitness System Based on Wearable Devices

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Abstract. Gamification of exercise has become a popular topic due to its motivational and engagement effects, which intends to result in increased exercise, activity, health, and fitness for everyday users. At the same time, wearable technologies have become a fast growing industry, providing consumers the ability to conveniently track their state of health and fitness efforts. Consequently, we propose that off-the-shelf commercial wearable technologies have great potential to be applied in gamification of fitness and exercise. In this paper, we utilize this concept through the design and implementation of a smartphone game application which uses wearable devices as input systems. The game supports two different wearable devices which are commercially available to end-users, and three types of activities were included in the gamified experience. These activities are performed as inputs to our mobile game. User tests evaluate the effectiveness of the combined use of games and wearable devices in promoting exercise. The usability of our proposed approach and effects of different factors within the system are also evaluated.

Keywords: Gamification · Exercise · Wearable device · Usability · Motivation

1 Introduction

The growing attention and interest towards exercise, health, and fitness has recently sparked the commoditization of a large number of wearable devices. These devices often range from simple activity trackers that monitor daily activities, and sleep patterns, to devices that integrate multiple sensors and can detect heart-rate, body temperature, muscle contraction intensity, hydration levels, and more [1]. Such devices, especially the activity trackers, are able to continuously collect data from the user's body and activities for analysis purposes, which not only could be used to monitor the state of health and fitness, but also help users develop better exercise routines. As wearables are becoming cheaper and more accessible, and data storage and processing capabilities improve, these devices and their associated applications are gradually becoming a part of our everyday lives.

In general, gamification is the notion of applying game design elements and mechanics to motivate and engage people in non-game contexts [2]. This practice has become a popular field of research due to increased capabilities and the wide use of smart phones and computers. Since exercise and fitness are often strenuous and

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potentially unattractive, alternative motivators such as entertainment and persuasive technologies are considered effective ways for appealing to a wider audience [3]. Lately, the use of gamification in different fields related to exercise, fitness, and health in general, has become popular.

Wearable technologies are suitable platforms for gamified health and fitness applications. As a result, some popular wearable's original applications have started to introduce gamified elements such as community, goals, and achievements. Yet, the existing wearable based applications rarely use actual gameplay mechanisms and real game experiences. Therefore, we have proposed an approach for gamification of exercise and fitness, where off-the-shelf commercial wearable technologies are utilized for interaction with real-time exercise games [4].

In this paper, we further explore this idea through the design and implementation of a smartphone game application and integration with two wearable devices. The game has been developed on the iOS platform and currently supports two types of wearable devices: Apple Watch as an example of a wrist-band tracker, and a 3-axis wrist-worn accelerometer (TI SensorTag CC2650) as an example of a simple do-it-yourself activity tracker which can also be worn on other parts of the body like the ankle. Both of these devices are commercially available to end-users. Three types of activities were included in the study, which are running on treadmill, biking on a trainer, and rope skipping. These activities are performed as input to our mobile game. User tests evaluate the effectiveness of the combined use of games and wearable devices in promoting fitness and a healthy lifestyle. Questionnaires are used to evaluate the usability of our proposed approach and effects of different factors such as the position to wear the device, different measurements, and different activities, overall satisfaction, motivation, reception compared to regular exercise, preference of game, preference of wearable, etc.

2 Related Work

Gamification is described as the process of using game-like elements and goal-based systems to increase motivation engagement in non-game contexts [5]. Practical applications of gamification, especially in the areas of health and fitness, has been growing for the past several years. The number of available applications in the App Store and Google Play under the category of health and fitness that contain gamified elements [6] is evidence to the popularity of this concept. These applications can be lightly gamified, for example most wearables' default applications such as leaderboard and challenges (Nike+ , Fitbit, Jawbone, Misfit, etc.), or heavily gamified, for example, the application *Dungeon Run* uses the camera to detect user movement and uses it as the input to the game.

In the past few years, researchers have devoted attention to gamified exercise, especially for running. For example, the smart phone game *Zombies Run* was an example where headphones were used to interact with users while they were running. This approach proved to have a positive and motivational impact [7]. In [8], Buttussi and Chittaro used and combined a GPS and a pulse oximeter worn on the user's ear, and proposed a user-adaptive game for jogging. Their study results showed that the game motivated users, while having other benefits such as training users to jog as a cardio-vascular exercise. In [9], Mokka et al. introduced a fitness game that users could play in a virtual environment for cycling. Their user test showed that virtual environments could be a motivating factor for exercise. Campbell et al. [10] discussed the notion of everyday fitness games and suggested that for applications that people frequently use in their everyday lives, designs need to be fun and sustainable, as well as adapt to behavioural changes. In [11], Wyle indicated that with the use of smart phones, gamified components such as a leaderboard, achievements and challenge amongst friends are effective ways of motivating and encouraging users to reach their personal goals and track their physical fitness activities. Bradley et al. [12] proposed a game that could motivate users to exercise both physical and mental aspects through the use of wearable ECG and EEG devices.

In [13], Ilona et al. stated that gamification was important in driving user motivation in different contexts, especially in health and education. They developed a learning solution using wearables to promote healthy ageing through a fitness-oriented massive online learning course with the use of integrated fitness trackers. It was illustrated that gamification is a significant element towards user engagement. In [14], Joey et al. proposed a mobile role-playing game that could motivate users to engage in exercise through the enjoyment of a game. Results showed that there was a significant connection between real-life activity and the in-game experience. They found that the in-game virtual characters could motivate users in exercise. In [15], Whitehead et al. also indicated that exercise games could motivate people to participate in more physical activities. Their work suggested that exercise games could be a useful solution to encourage people to exercise more, and the design should consider both incentive and physical benefits.

Most wearable devices in today's market, especially the new generation of activity trackers, are affordable and easy to purchase. Many of them even provide an application program interface (API) for third party developers to build applications. In [16], Miller has indicated that researchers are now able to study the fitness tracker as more than just a personal data-gathering tool since more interactions and social elements could be added in. In [17], Stefan et al. proposed an idea that with the prevalence of wearable devices, the input and output possibilities of smartphones can be further extended with both new sensors and actuators. New applications could be designed to enrich the interaction experience with the development of wearable technologies.

3 Research Approach

3.1 Overview

We designed an application (game) where off-the-shelf commercial wearables are used as input devices for gamified exercise. The game was developed on the iOS platform and currently supports Apple Watch (http://www.apple.com/watch/) and TI SensorTag (www.ti.com/sensortag), both of which are commercially available. Successive to application design and implementation, the user study was designed and carried out. Finally, the results were analyzed and conclusions were made regarding the proposed concept. Figure 1 illustrates the overall process for this work.

Fig. 1. A schematic of our study: a gamified exercise application using wearable devices was designed and implemented. Subsequently, user studies were designed and carried out. Finally, the data was analyzed and interpreted to evaluate the effectiveness of our proposed approach.

With the robust and dynamic basis that was created in this work, additional wearable devices can be added to the study in the future. The three different activities tested in this study were running on a treadmill, biking on a trainer, and rope skipping. These activities were monitored by the wearable devices and respective features were used as inputs to the game through Bluetooth (BLE in our case) in real time. User studies were designed to evaluate the effectiveness of the combined use of activities and wearable devices for promoting exercise (in terms of increased activity level, enjoyment, and motivation), and understand the impact of gamification in motivating exercise and making the experience more interesting. Additionally, the usability of the system was investigated.

3.2 Application Design and Implementation

The iOS application *StrayBird* was implemented for this work. The application communicates with wearable activity trackers in real-time and uses data received from these devices as inputs for the game. The game requires that the player engages in running, cycling, or rope skipping motion to control the movements and actions of the principal character, which is a bird that has fallen behind his travelling companions. The objective is to regroup with the flock before time runs out and before the group reaches its intended destination. There are also physical and environmental parameters that may affect the movement behaviour of the bird and flock. The game features a mission-based structure and point-based system. It is based on a linear progression structure and consists of unlockable levels that increase with slight difficulty and differ to a certain degree in gameplay. Figure 2 presents snapshots from different sections of the application, namely choice of exercises, game view, and result view.

We have connected two devices to this application: Apple Watch and TI SensorTag. The former is an example of a high-end off-the-shelf product, while the latter is an example of a simple do-it-yourself system that can be adjusted for different applications. The data from the Apple Watch can be directly transferred to iOS HealthKit via Bluetooth and the app will be able to obtain data from HealthKit, though there is approximately 10 s of uncontrollable delay during the data transmission. For the TI SensorTag we could directly access the raw data from its accelerometer, so we implemented an algorithm to calculate the speed from raw acceleration data.

Fig. 2. Screen shots from our application are illustrated. From left to right: choice of exercises, game view, and result view

3.3 User Study

20 participants participated in our study, each of whom performed two sessions of exercises. The two wearable products and three different games (running, cycling, and rope-skipping) were randomly combined and assigned to participants. The Apple Watch was not used with cycling because it can only be worn on the wrists. Subjects took part in a maximum of two different trails. Each trial took 10-15 min followed by a 10-min rest and recovery period. Each exercise mode prompts the user to perform a specific exercise (run, cycle, or skip ropes). Figure 3 shows snapshots of the three exercise modes. During each game, metrics such as speed, traveled distance, and calorie expenditure are recorded from the user. Once an exercise was completed, during the rest period, participants were asked to fill a questionnaire for each game that they played. This included questions on level of enjoyment, fatigue, sense of accomplishment, motivation for more exercise, and usefulness of the application.

Fig. 3. The three types of exercises in our user study: running, cycling, and rope skipping

3.4 Data Analysis

Two-way between-groups analysis of variances (ANOVA) was conducted to analyze the main effects of different game modes (exercise and device) and different game-play parameters (perceived by users). The investigated parameters are: enjoyment, fatigue, accomplishment, motivation, usefulness, satisfaction, and preference. 7-point Likert scale was used in this study. We used R to run the analysis. The different combinations of exercise and wearable device are presented and labeled for future reference (Table 1).

Table 1. Combination of exercises and wearable devices

	Apple Watch	TI SensorTag
Running	A	B
Cycling	–	C
Rope skipping	D	E

4 Results and Discussions

20 volunteers participated in this study. 10 were males and 10 were females. Their average age was 25.25 with the standard deviation of 4.27. The average weight was 62.35 kg with a standard deviation of 11.9. The average height was 170.65 cm with a standard deviation of 6.80. Their average hours of exercise per week was 4.53 h with a standard deviation of 2.20. Their average hours of playing computer/mobile games per week was 4.95 h and the standard deviation was 4.95. 8 of the participants (40 %) previously (or currently) owned an activity tracking wearable device.

Participants were asked whether they had fun and enjoyed their experience playing the games. Figure 4 shows the average and standard deviations of the scores for this parameter where $M_A = 5.14$ and $SD_A = 0.69$, $M_B = 5.43$ and $SD_B = 0.98$, $M_C = 5.29$ and $SD_C = 1.11$, $M_D = 4.71$ and $SD_D = 1.11$, and finally $M_E = 5.57$ and $SD_E = 1.40$. ANOVA shows no significant effect for either factor ($F(2,29) = 0.07$ with $p = 0.93$ for exercise, $F(1,29) = 1.95$ with $p = 0.17$ for device, and $F(1,29) = 0.49$ with $p = 0.49$ for the interaction between them). This outcome can point to the fact that the sense of fun and enjoyment is mostly derived from the actual game content itself (digital aspect) rather the interaction and communication medium, or even the exercise.

When asked to rate the level of fatigue felt after each game, participants rated rope skipping as the most fatiguing activity among the three exercises. Figure 5 illustrates the results where $M_A = 2.71$ and $SD_A = 1.11$, $M_B = 3.14$ and $SD_B = 1.77$, $M_C = 2.86$ and $SD_C = 1.86$, $M_D = 5.86$ and $SD_D = 1.35$, and $M_E = 5.28$ with $SD_E = 2.06$. ANOVA indicates that the type of exercise has a significant effect at the $p < 0.001$ level on the feeling of fatigue, with $F(2,29) = 10.74$ and $p = 0.0003$. The results show that skipping was significantly more fatiguing than running and cycling ($M_{Skipping} = 5.57$, $SD_{Skipping} = 1.70$, vs. $M_{Cycling} = 2.86$, $SD_{Cycling} = 1.86$ and $M_{Running} = 2.93$, $SD_{Running} = 1.44$). There is no significant effect for device ($F(1,29) = 0.01$, $p = 0.91$) and the interaction of exercise and device ($F(1,29) = 0.63$, $p = 0.43$). In general, rope skipping is known to be a high-intensity exercise, which can significantly impact the amount

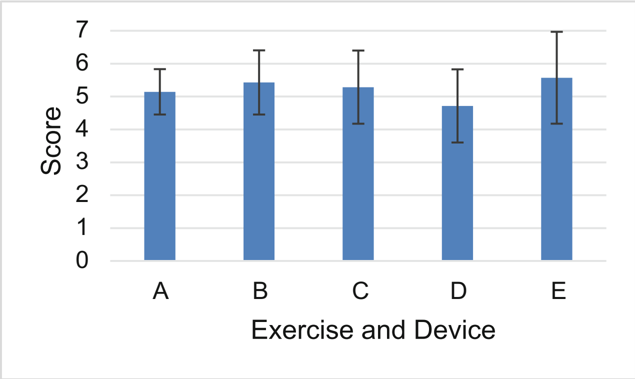

Fig. 4. User enjoyment for different modes of the game

of fatigue. The results confirm this notion. As a result, this mode of the game can be used as the *difficult* level. The wearable devices are both light in terms of weight, and do not impact the users' performance. It is therefore fair to say that non-intrusive devices such as these are potentially the right choice of device for gamified exercise.

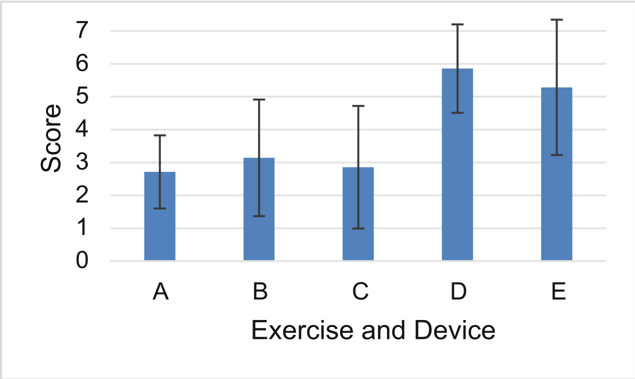

Fig. 5. The amount of fatigue for different modes of the game

Following the game session, participants were asked if they felt as if they had exercised/worked out successfully throughout the game. The results were M_A = 5.43 and SD_A = 1.40, M_B = 5.86 and SD_B = 0.90, M_C = 5.71 and SD_C = 1.11, M_D = 5.00 and SD_D = 1.41, and M_E = 6.58 with SD_E = 0.53 as shown in Fig. 6. There was a significant effect for different devices at the $p < 0.05$ level ($F(1,29) = 5.57$, $p = 0.02$), with the mean score for TI SensorTag (M = 6.05, SD = 0.92) being significantly higher than Apple Watch (M = 5.21, SD = 1.37). While the significance of this difference is not particularly strong as per the ANOVA result, we believe that the delay in the Watch could have caused participants to perceive a lack of correlation between their exercise and corresponding accomplishments in the game. This could have caused them to believe that it was not them that in fact accomplished the exercise/game goals. In addition, there is no significant effect for exercise ($F(1,29) = 0.06$ with $p = 0.94$) and the interaction of exercise and device ($F(1,29) = 1.82$ with $p = 0.19$).

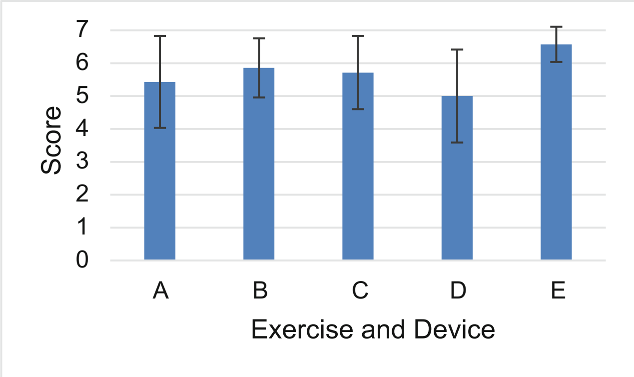

Fig. 6. Sense of accomplishment for different modes of the games

When asked whether they found this kind of application motivating for exercise, promising scores were achieved. As shown in Fig. 7, $M_A = 5.57$ and $SD_A = 0.79$, $M_B = 6$, $SD_B = 0.58$, $M_C = 5.57$ with $SD_C = 1.13$, $M_D = 5.43$ with $SD_D = 0.98$, and finally for $M_E = 6.43$ and $SD_E = 0.53$. There was a significant effect for different devices at the $p < 0.05$ level ($F(1,29) = 5.14$, $p = 0.03$), with the mean score for TI SensorTag ($M = 6.00$, $SD = 0.84$) being significantly higher than Apple Watch ($M = 5.50$, $SD = 0.85$). In addition, there is no significant effect for exercise ($F(1,29) = 0.43$ with $p = 0.65$) and the interaction of exercise and device ($F(1,29) = 0.82$ with $p = 0.37$).

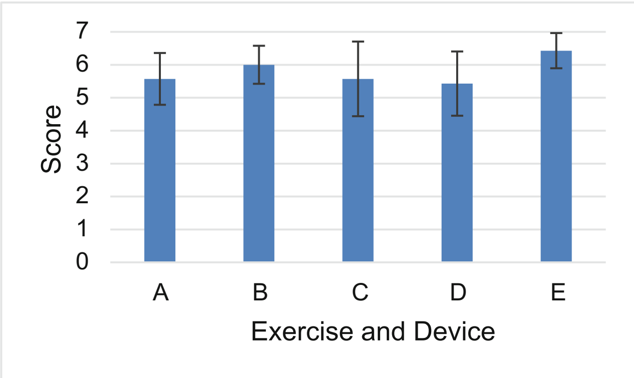

Fig. 7. Motivation for more exercise based on playing the game in different modes

Participants were asked whether they would like to use this application again. The results are presented in Fig. 8 where $M_A = 5.43$ with $SD_A = 1.27$, $M_B = 6.00$ with

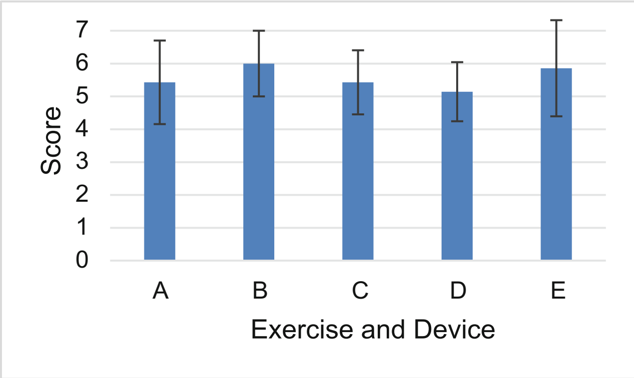

Fig. 8. Usefulness of the application based on the played game mode

SD_B = 1.00, M_C = 5.43 and SD_C = 0.98, M_D = 5.14 with SD_D = 0.90, and M_E = 5.85 with SD_E = 1.46. No significant effect is observed ($F(2,29) = 0.19$ and $p = 0.83$ for exercise, $F(1,29) = 2.22$ with $p = 0.15$ for device, and $F(1,29) = 0.03$ with $p = 0.87$ for the interaction between the two). Similar to the motivational aspects of the application, the results are promising and users find it useful.

Finally the overall satisfaction and preference of participants was asked. For satisfaction, M_A = 5.29 and SD_A = 0.76, M_B = 5.86 with SD_B = 0.90, M_C = 5.71 and SD_C = 0.95, M_D = 5.0 with SD_D = 1.15, and for M_E = 5.71 with SD_E = 1.11, as shown in Fig. 9. No significant effect was observed for device ($F(1,29) = 2.98$, $p = 0.10$), exercise ($F(1,29) = 0.35$, $p = 0.71$) and the interaction of the two factors ($F(1,29) = 0.04$, $p = 0.85$). The scores for preference were as follows M_A = 5.14 and SD_A = 0.69, M_B = 6.0 and SD_B = 0.82, M_C = 5.86 and SD_C = 1.07, M_D = 4.86 with SD_D = 1.57, and finally M_E = 6.0 with SD_E = 0.82, as shown in Fig. 10. The effect of device was significant at the $p < 0.05$ level ($F(1,29) = 6.45$, $p = 0.02$) with the SensorTag ($M = 5.95$, $SD = 0.86$) being higher than the Watch ($M = 5.00$, $SD = 1.18$. In addition, there is no other significant effect for exercise ($F(1,29) = 0.39$, $p = 0.68$) and interaction between device and exercise ($F(1,29) = 0.13$, $p = 0.72$).

The absence of a significant effect in satisfaction can be due to the fact that the concept of gamified exercise, especially through wearable devices, is quite novel and attractive for participants. As a result, relatively similar satisfaction scores were observed. Despite this similarity, preference scores were significantly higher for the SensorTag. While this significance was weak, the underlying reasons can be the lag in the Watch, which can make the experience subpar in real-time interactive applications. Software updates that enable access to the inertial measurement unit (IMU) data in real-time can alleviate this issue and increase satisfaction scores.

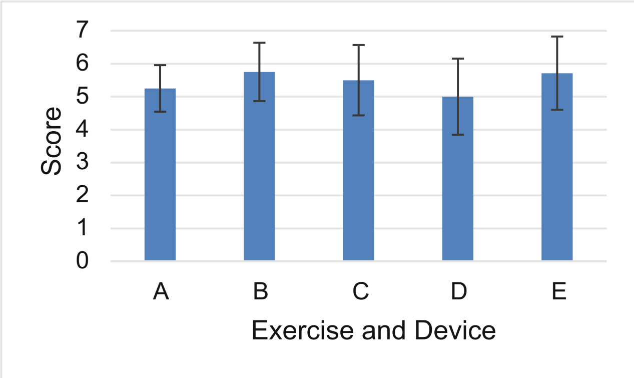

Fig. 9. Overall satisfaction of the different modes

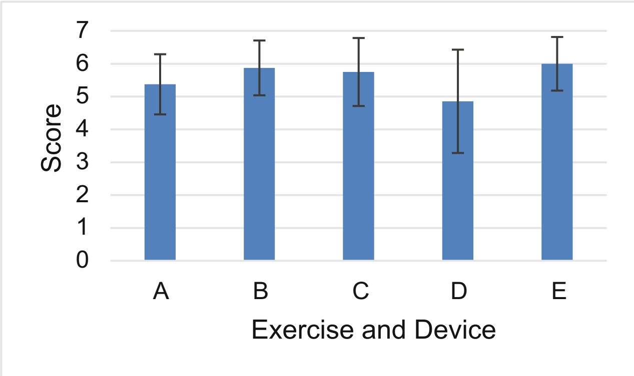

Fig. 10. Preference scores for different combinations of exercise and device

When asked which device they believed represented their movements more accurately, only 13.55 % of participants chose the Watch, while 86.45 % picked the SensorTag, mentioning the real-time performance as the key reason for their choice. This notion highlights the importance and impact of real-time interaction. While some game designs could be better suited for non-realtime applications (for example games that are based on post-workout leader boards), we believe realtime systems are more engaging and attractive for gamified exercise. It is therefore important to utilize wearable products that provide real-time access to IMU or other sensor data through their API.

5 Conclusion

We proposed the use of wearable devices for gamified exercise, towards which we designed and implemented a smart phone exercise game that communicates with wearable devices in real-time and receives user inputs accordingly. Combinations of three different exercises (running, cycling, rope skipping) and two different types of wearable devices (Apple Watch and TI Sensor Tag) are selected as different gaming modes. We performed a detailed user study to evaluate the usability and outcomes of the system. The results show that the approach is motivating and engaging. Users demonstrated high satisfaction towards the application and enjoyed the experience. Factors such as user's preferences towards different types of exercise or devices were also investigated.

In our future work, we will improve the game according to user's suggestions and feedbacks. These suggestions included adding different elements to the gameplay to make it more attractive, providing real-time multiplayer mode, and letting users input their body information so that we could assign personalized goals in the game. We will also add a control group to this study for better analysis of the results. A broader range of user needs can also be considered by adding more game modes (exercises and wearables). Furthermore, other parameters such as calories, heart-rate, and others will be monitored in order to better understand the performance and engagement of users. Finally, a long-term user study will be carried out to investigate the medium and long term effects of the proposed concept in motivating users to exercise and have a healthier lifestyle.

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