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## **Make people move**

Utilizing smartphone motion sensors to capture  
physical activity within audiences during lectures

# Make people move: Utilizing smartphone motion sensors to capture physical activity within audiences during lectures

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## ABSTRACT

It takes only about 10-30 minutes into a sedentary lecture before audience attention is decreasing. There are different ways to avoid this. One is to use a web-based audience response systems (ARS), where the audience interact with the lecturer through their smartphones, and another is to take short breaks, including physical movements, to re-energize both the body and the brain.

In this study, these two methods have been combined and explored. By utilizing the motion sensors that are integrated in almost every smartphone, a physical activity for a lecture audience was created and implemented in the ARS platform Mentimeter. The proof of concept was evaluated in two lectures, based on O'Brien and Toms' model of engagement. The aim was to explore the prerequisites, both in terms of design and implementation, for creating an engaging physical activity within a lecture audience, using smartphone motion sensors to capture movements and a web-based ARS to present the data.

The results showed that the proof of concept was perceived as fun and engaging, where important factors for creating engagement were found to be competition and a balanced level of task difficulty. The study showed that feedback is complicated when it comes to motion gesture interactions, and that there are limitations as to what can be done with smartphone motion sensors using web technologies. There is great potential for further research in how to design an energizing lecture activity using smartphones, as well as in exploring the area of feedback in motion gesture interaction.

## Author Keywords

Smartphone motion sensors; Motion gesture interaction; Audience Response Systems

## ACM Classification Keywords

Human-centered computing → Ubiquitous and mobile computing → Ubiquitous and mobile devices → Smartphones

## 1 INTRODUCTION

### 1.1 Background

In smartphones, motion sensors are almost always integrated in the hardware. Gyroscopes, tri-axis accelerometers and orientation sensors are accessible while developing native

applications but can also be used in web browsers. The motion sensors are for example used natively to detect device orientation to adjust the screen rotation, but they are also used for motion-based health tracking such as monitoring of sleep [12], posture [11] and physical activity [18].

Health tracking using smartphone motion sensors has repeatedly been shown to motivate people to a more active lifestyle [2, 4]. It is well known that it is good to perform physical activities, but it is not only from a physical health perspective it is beneficial - it is also good for the brain. Taking short breaks including physical activity regularly during the workday has been shown to increase both work motivation and task performance [3].

For many, a regular workday includes long sedentary meetings or lectures. Concentration usually drops after about 10-30 minutes into a sedentary lecture [10, 20], but this can be avoided either through brief mental breaks [10] or through variation in the lecture content [20]. To create variation in lecture content, a tool that can be used is an Audience Response System (ARS) where the audience can interact with the presenter through their smartphones, for example by voting on questions asked by the presenter [7].

To further develop the concept of ARS, encourage physical activity within sedentary tasks and to utilize the capabilities of smartphones, this study aims to explore how to create a physical activity within an audience during a lecture by using smartphone motion sensors. Through a concept study where the smartphone is used as a handheld motion gesture controller, a proof of concept is designed and implemented in an existing ARS. The concept is evaluated with two audiences based on engagement - a quality of user experience with focus on enjoyment [15] and the system's ability to hold the users attention [14].

The study is carried out at Mentimeter<sup>1</sup>, which is a web-based ARS used for workshops and lectures, both at companies and in educational settings all over the world. The company was founded in 2012 and was in 2018 the fastest growing startup in Sweden<sup>2</sup>.

### 1.2 Research Objective

The purpose of the study is to explore the prerequisites for using smartphone motion sensors for motion gesture

<sup>1</sup> <https://www.mentimeter.com/>

<sup>2</sup> <https://thenextweb.com/tech5/country/sweden>

interaction, both in terms of engaging interaction and implementation. The research question explored were therefore:

*How can an engaging physical activity within an audience during a lecture be designed and implemented, using smartphone motion sensors to capture movements and a web-based audience response system (ARS) to present the data?*

### 1.3 Delimitations

One aim is that the concept should work in a real lecture setting, which means it needs to be compatible with different hardware and a diverse audience. Since the idea is to use a web-based audience response system, the implementation is based on smartphone browser technology and like in a regular ARS, a separate screen is used for the output.

## 2 THEORY AND RELATED RESEARCH

### 2.1 Movement and concentration

It is well known that it is healthy to regularly engage in physical activity, and it is not only from a long-term health perspective that it is beneficial. For example, to take “micro-breaks” during the workday, including physical activity such as stretching or taking short walks, is proven to increase task performance and work motivation. It can also contribute to a positive mood and to decrease fatigue [3]. While re-energizing the body and brain, micro-breaks including physical activity also give the brain time to process information [8]. A definition of how a physical micro-break should be performed is hard to find, but the Professional Associations for Physical Activity in Sweden (YFA) recommend micro-breaks in terms of regular pauses including some form of muscle activity, performed during a few minutes [6].

### 2.2 Motion gesture interaction

Interaction through three-dimensional gestures holding a device is defined by Ruiz, Li and Lank [17] as motion gestures. The device should be equipped with motion sensors, which the user translates or rotates to interact. Motion gesture interaction is for example used in gaming consoles, such as Nintendo Wii and the Wii Remote<sup>3</sup>. The Wii Remote is a hand-held wireless controller which captures the user movements using several sensors and is used for interaction in video games. Besides an accelerometer and orientation sensor, the Wii Remote also has a light sensor with an emitter just beneath or above output display for the game, which allows it for six degrees of freedom.

In more ubiquitous consumer devices such as smartphones, tri-accelerometer, gyroscopes and orientation sensors are often integrated in the hardware. These are used to identify

rotation and tilt of the device to adjust the screen rotation but can also be used for collecting data about the user, like monitoring of physical activities [11, 12, 18]. Unlike the Wii Remote, smartphone's motion sensors cannot in general recognize position of the device, but only tilt or acceleration.

The use of smartphone motion sensors has previously been explored in a number of different settings. Kerwin, Nunes and Silva explored the use of smartphones to monitor fall risk for seniors while dancing [19] and Lu et al. used a smartphone to detect different activities while playing basketball [9]. Smartphone motion sensors for motion gesture interaction have also been examined in multiple studies. Ruiz et al. have for example used this technology for smartphone navigation such as for handling incoming calls and for navigation in menus and applications [16, 17]. In another study conducted at SAIT (Samsung Advanced Institute of Technology), motion gestures in smartphones were used in interactive games and musical instrument applications by gesturing numbers and patterns in the air. For this, an algorithm was created using advanced pattern recognition and analysis of 3082 gestures [1].

In 2007, when tri-axis accelerometers in phones were fairly new, Vajk et al. developed two games where a phone was used as a controller, similar to the Wii Remote. To enable a greater amount of movement for the players, the games used a large screen for the output where visual elements moved according to the tilt of the phone. They suggested that even though the phone could not rival the Wii, the accelerometers opened up for new innovative games running on mobile [21].

### 2.3 Using smartphone motion sensors

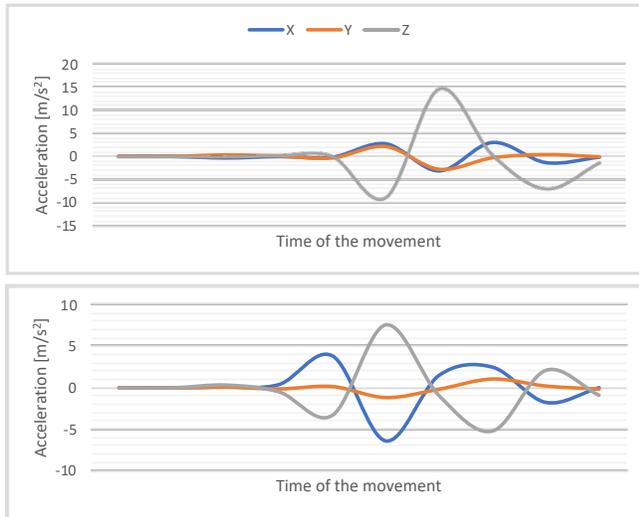
The smartphone motion sensors can be used when building native applications but can also be accessed in the web browser using Web APIs such as DeviceOrientationEvent<sup>4</sup> and DeviceAcceleration<sup>5</sup>. The gyroscope data in the device orientation is measured in degrees in relation to gravity and the acceleration is measured in  $m/s^2$  with the axes relative to the four cardinal points and to gravity. In general, the accelerometer data is provided in three axes, but the sensor data can be interpreted differently in different devices and browsers and in some cases the axes can be reversed.

In Figure 1, an example of data from an accelerometer sensor can be seen in two graphs. The movement performed in the first graph is starting with the smartphone lying flat on a surface with the screen facing up. The smartphone is lifted straight up about 20 cm in the z-plane, and then back down again to the starting position. The z-curve shows that the movement is performed in z-plane, with some noise in the x- and y-plane since the movement is performed by a human and not a robot.

<sup>3</sup> [https://en.wikipedia.org/wiki/Wii\\_Remote](https://en.wikipedia.org/wiki/Wii_Remote)

<sup>4</sup> <https://developer.mozilla.org/en-US/docs/Web/API/DeviceOrientationEvent>

<sup>5</sup> <https://developer.mozilla.org/en-US/docs/Web/API/DeviceAcceleration>



**Figure 1** Plot of smartphone accelerometer data in three axes. In the first graph the phone is positioned flat relative to the ground and lifted straight up, about 20 cm, and down again to starting position. In the second graph the same movement is performed, but with the phone tilted 45 degrees in the x-plane.

In the second graph in Figure 1, the same smartphone is tilted approximately 45 degrees in the x-plane before performing the same movement as before; lifting the smartphone approximately 20 cm in the z-plane. The output gives a similar curve as in the first graph for the z- and y-plane, but the x-plane has a more defined curve, showing that the angle of the device as a large effect on the accelerometer data.

#### 2.4 Audience response systems

An Audience Response System (ARS) is an electronic tool for communication during lectures and is used to improve audience engagement and attention in the classroom as well as provide audience feedback to the presenter [7]. Lecturers can for example use ARS's to ask questions to the audience, to which the audience can respond by using remote devices, and the results are then instantly presented to the audience in a visual format [7].

There are several web-based ARSs on the market such as Mentimeter, Kahoot<sup>6</sup> and Poll Everywhere<sup>7</sup>. These ARSs allows the audience to use their smartphones for interaction, and the results are displayed on the presenter screen.

#### 2.5 Characteristics of engagement

For all interactive systems and applications, usability is an important factor. In many cases though, usability alone is not enough. There is a need to move beyond usability and

functionality, and also provide an *engaging* experience [5, 13, 14]. Even though many agree that engagement is an important factor for a successful technology, measuring and defining engagement is a challenging task. Chapman said that something engaging is “[...]something that draws us in, that attract us and holds our attention.” [14] while Quesenbery defined it as a quality of user experience, related to a user’s first impression of a system and enjoyment of using it [15].

In 2008, O’Brien and Toms' conducted a multidisciplinary study to deconstruct and define the term. Their definition of engagement ended up in being:

“Engagement is a quality of user experience with technology that is characterized by challenge, aesthetic and sensory appeal, feedback, novelty, interactivity, perceived control and time, awareness, motivation, interest and affect.” [14]

Besides defining attributes, O’Brien and Toms' also observed different phases of engagement: point of engagement, period of engagement and disengagement. They suggested that a user can be either engaged or non-engaged, but also that the engagement moves in a cycle and varies over time. They also separated the attributes that they assigned to engagement into three threads of experience; sensual, emotional and spatiotemporal, which can be seen in Table 1.

#### 2.5.1 Adaption of engagement model for the purpose of this study

In this study, O’Brien and Toms' model of engagement was used as a framework for evaluation, but to fit the context of a lecture environment, the framework was adapted.

In the context of a lecture activity, the user is asked in an organized setting to take part of the task, meaning there is no need to “take one’s time” to engage in the activity. There is also no big risk of external physical disruptions or lack of time to finish that could cause disengagement, as the physical environment that the user is in is dedicated to the activity. These attributes for engagement were therefore not considered for the evaluation.

Factors that were more interesting for the context, on the other hand, were the attributes related to the period of engagement such as social awareness, enjoyment and feedback. It was also important to avoid disengagement due to lack of technical stability or a too high or low level of challenge in the activity.

<sup>6</sup> <https://kahoot.com/>

<sup>7</sup> <https://www.poll.everywhere.com/>

<i>Threads of experience</i>	<i>Phases of engagement</i>		
	<b>Point of engagement</b>	<b>Period of engagement</b>	<b>Disengagement</b>
<b>Sensual</b>	Aesthetically pleasing  Novel presentation of information	Graphics that keep attention and interest to evoke realism  “Rich” interfaces that promote awareness of others or customized views of information	Inability to interact with features of the technology or manipulate the interface features (usability)  Lack of too much challenge
<b>Emotional</b>	Motivation to accomplish task or to have an experience  Interest	Positive affect: Fun, enjoyment, physiological arousal	Negative affect: Uncertainty, information overload, frustration with technology, boredom, guilt Positive affect: Feelings of success and accomplishment
<b>Spatiotemporal</b>	Becoming situated in the “story” of the application  Ability to take one’s time in using the application	Perception that time has passed very quickly  Feedback and control  Lack of awareness of others when the engagement revolved around social interaction	Not having sufficient time to interact with or time to devote to the application Interruptions and distractions in physical environment

**Table 1. Attributes of engagement, explained and separated based on threads of experience and phase of engagement according to O’Brien and Toms' model of engagement [14].**

### 3 METHOD OVERVIEW

To answer the research question, how to design and implement a physical activity within an audience during a lecture, a concept study was conducted, and a proof of concept was implemented in the ARS platform Mentimeter. The study was conducted in two phases, as seen in Figure 2, the first focusing on technology and implementation and the second on interaction and engagement.

The first part of the study included exploring technology and implementation. This was done through prototyping and exploring the sensors. A prototype was built and tested with users to discover what requirements there were for using the sensors for motion gesture interaction. Based on that, but also based on previous research and the context, design requirements were defined before creating the final proof of concept.

The second phase of the study was focused on interaction and engagement. Based on the design requirements, a proof of concept was designed and implemented into the Mentimeter platform. The final concept was then evaluated with two audiences during two lectures with a focus on engagement.

### 4 PROTOTYPING WITH SENSORS

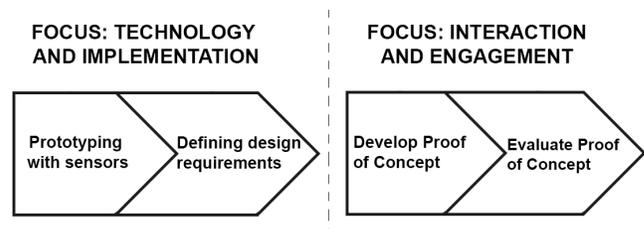
To discover what requirements there were for using smartphone motion sensors for motion gesture interaction, the sensors were first explored by developing different

interactions. A prototype was then developed and tested with users, with a focus on the functionality of the sensors.

#### 4.1 Development

Before creating the prototype, different interactions were built to discover the accuracy as well as limitations of the sensors. Both accelerometer sensors and gyroscopes were used. In all cases, a smartphone was used for input and a computer screen for displaying the output. Interactions that were built were: shaking the smartphone while measuring intensity, shaking the smartphone while measuring the plane of the movement, tilting the smartphone to control the position of an object on the computer screen and attempts to calculate the direction of different movements.

For the prototype, the accelerometer sensor was chosen as the main sensor over the gyroscope. This was because the accelerometer was better at capturing large movements, and



**Figure 2. Overview of the method for the concept study.**

the goal was to get the audience moving, while the gyroscope only measured the tilt of the smartphone.

#### 4.2 Prototype

The prototype consisted of an imitation game. The game allowed for up to four players at once and the task was to imitate movements shown on a presenter screen while holding a smartphone. The game consisted of five different movements, presented for a few seconds each, with breaks in-between. The five movements were: wave left to right with hands up, shake the phone with hands down, wave hands back and forth with hands up, wave left to right with hands down and shake the phone with hands up. Static images of the five movements can be seen in Figure 3. The game was developed using web technologies for web browsers and a real-time messaging API from PubNub<sup>8</sup>.

During the movements, a score was generated for each player. The score was calculated by adding the absolute values of the acceleration sensor output every 0,2 second.

For the last evaluation, the prototype was refined by adding a threshold to the acceleration output to filter out very large values. The time of the movements was also increased, from 4 seconds per movement in the first iteration to 7 seconds, and a countdown was added before starting the movements.

#### 4.3 Evaluation of prototype

To evaluate the functionality of the prototype, a user test was conducted with 13 students. The participants were in the age group 25-34 and all used their own smartphones. Four participants had the operating system Android and nine the operating system iOS. The first iteration of the prototype was tested with eight participants and the second iteration with five.

During the test, the output from the sensors was collected and observations were made. The results from the testing were used to define design requirements for the final proof of concept.

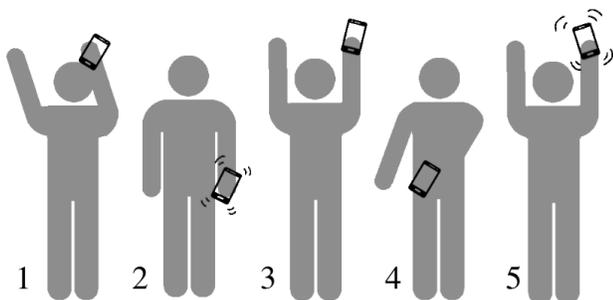


Figure 3. Static images of the five different movements in the imitation game.

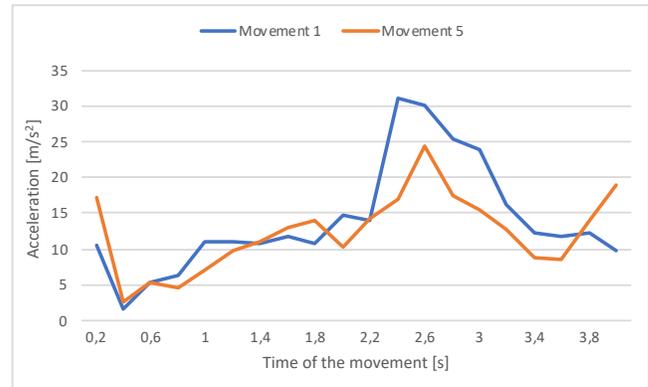


Figure 4 The average acceleration data over time for movement 1 and 5, with noticeable minimums after 0,4 seconds, indicating that the user is not moving.

#### 4.4 Result

The sensor data gathered from the different participants were all within a comparable range, and no differences could be noticed in the output based on hardware or browsers. At times some outliers could be spotted, which strongly affected the game by making the score for that specific participant much higher. This was the reason for adding a threshold for the last tests of the prototype, to filter these out, which helped to improve the score.

In Figure 4, a plot of the average acceleration change throughout two of the five movements can be seen. 0,4 seconds into the movement, a minimum value appears. This indicates that the user was not moving, or was moving very little, and the same pattern followed in all of the five movements. For the second iteration of the prototype, a countdown was therefore added before starting the movements. This resulted in a more even acceleration change throughout the movements and no minimum value in the beginning, which indicates that the participants started the movements with less delay.

The users were aware of that the sensor data was measured, but not for what reason. The instruction given to the users was to play the game. After a few sets of movements, some users tried to “break” the system by performing fast and intense movements that generated a high score instead of the movements shown in the instructions. As the score was only calculated by adding pure acceleration data, the fast and intense movements with a high acceleration generated a better score than movements that actually imitated the animations in the game.

#### 5 DEFINING DESIGN REQUIREMENTS

Based on the outcome of the initial prototyping phase and the user testing, conclusions could be made regarding the technical solution and design. In this section, these findings will be discussed along with context-based prerequisites for the design, such as being in an audience during a lecture.

<sup>8</sup> <https://www.pubnub.com/products/realtime-messaging/>

### 5.1 Design for an audience

The physical setting where a lecture takes place can differ, but for the purpose of this study, it was assumed that the space to perform movements during a lecture is often limited. To make the activity diverse and suitable for various settings, the movements for a physical lecture activity should therefore be while standing up, but without moving the feet, and instead focusing on moving arms and upper body.

The activity should also be suitable for a wide target group, since an audience in a lecture includes a diverse group of people. The movements should therefore be relatively simple, which could make it easier for everyone to feel motivated to join. Still, the level of challenge should not be too low, since this could be a cause for disengagement [14].

As the focus of most lectures is to educate, the activity should not be too long or take too much focus from the real purpose. To still be suitable as a micro-break, the activity needs to be performed during a few minutes, and include some kind of muscle activity [6].

### 5.2 Calculating score

The activity was made into a game, as the competition and playfulness were hypothesized to motivate the audience to participate, with a score as feedback to the players on their performance.

In the prototype, the score was calculated by summarizing data from the acceleration sensor. With this method, it was easy for the players to “beat the system” and stop performing the correct movements to get a higher score. As the score with this method does not correspond to whether or not you are actually playing the game fairly, a different feedback method needs to be provided.

Another way to calculate a score could be to detect the direction of a movement and give score based on that, but as seen in Figure 1 in Section 2.3, the angle of the device will strongly affect the sensors’ perceived direction of the movement. To be able to detect direction of the movement the player would need to hold the device in a fixed angle throughout the movement. To not restrict the players in the interaction, this method for calculating scores should not be used.

### 5.3 Issues when using the smartphone as controller

When moving a smartphone in an engaging activity, it is important to make sure the user feels in control of the interaction. If performing fast or intense movements, there could be an increased risk of dropping the smartphone. To avoid this, big and calm movements are to prefer.

Also related to the grip of the smartphone is the risk of accidentally touching buttons on the screen or on the side of the device. This could lead to closing browser windows which would stop the tracking of the activity. Even less

control over the grip could come when performing fast or intense movements. Again, to ensure a good grip, big and calm movements is to prefer.

When developing for the motion sensors using browser technology, native functionalities in the smartphone need to be considered. For example, there is a built-in gesture interaction in iOS, called Shake to Undo<sup>9</sup>, which appears when shaking the phone after entering text into an input field. The smartphone also often activates a screen lock when being inactive for a while. The time for this varies, but when it is activated it would stop the tracking of the activity. With native applications this could have been avoided, but since browser technology is more limited, this instead needs to be considered when developing.

## 6 FINAL PROOF OF CONCEPT

Based on the design requirements, a proof of concept was designed and implemented in the Mentimeter platform. The proof of concept was then tested on two different audiences with focus on engagement.



Figure 5. Presentation of the upcoming movement.

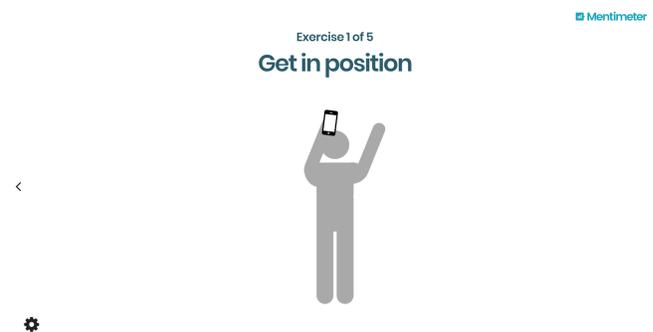


Figure 6. Instruction to the users to get in position.

<sup>9</sup> <https://developer.apple.com/ios/human-interface-guidelines/user-interaction/undo-and-redo/>

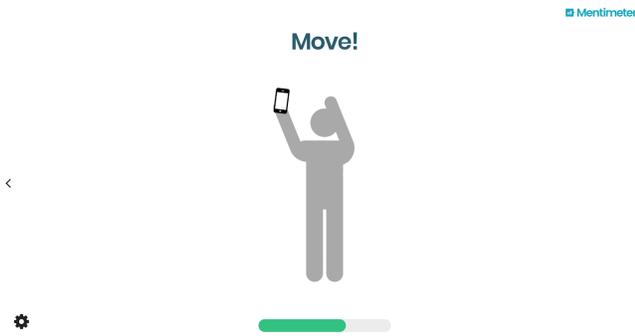


Figure 7. Animation with progress bar.

### 6.1 Proof of concept

The proof of concept was similar to the imitation game used in the prototype but allowed for a larger number of users (50+) and was implemented in Mentimeter, which made it look a lot like a real product. A framework to disable screen lock was used<sup>10</sup>. Each player was assigned a name and five physical movements were performed after each other with breaks in-between. Each set was first introduced on the presenter screen with a short instruction and image of the upcoming animation, Figure 5. A preparation slide was then presented, Figure 6, instructing the user to get in position. A countdown was displayed during the last 3 seconds before the animation started and the players were then instructed to move, Figure 7. Each movement lasted for 7 seconds during which a progress bar displayed the time.

During the movements, sensor data was captured for each player. The movements were analyzed based on frequency of changes in direction and intensity of the movements, which generated a score. An ideal frequency and intensity was set based on the previous user testing, and the score was calculated like,

$$score(f, i) = score_{max} \times \frac{i}{i_{ideal}} \times \frac{f}{f_{ideal}}$$

Where the maximum score per set ( $score_{max}$ ) were 1000 and the intensity was defined like,

$$i = \begin{cases} i_{mean} \times 0.01, & i_{mean} > 3 i_{ideal} \\ 0.5 i_{ideal} (i_{mean} - i_{ideal}), & i_{mean} > i_{ideal} \\ i_{mean}, & i_{mean} \leq i_{ideal} \end{cases}$$

With  $i_{mean}$  as the average intensity of the extreme values and  $i_{ideal}$  30. And where,

$$f = \begin{cases} 0.5 f_{ideal} (f_{total} - f_{ideal}), & f_{total} > f_{ideal} \\ f_{total}, & f_{total} \leq f_{ideal} \end{cases}$$

Where  $f_{total}$  was the total number of extreme values ( $f_{total} \leq 70$ ) and  $f_{ideal}$  was 28.

This means the score would be better the closer to the ideal movement the player was, and both too much or too little movement would result in a lower score.

After each set, a high score with the top 10 players and their total score was displayed on the presenter screen. Each user's individual score as well as ranking was displayed on each user's phone.

### 6.2 Evaluation of Proof of Concept

The proof of concept was evaluated with a focus on engagement, through two audience test sessions. The audience was asked to participate in the game with their own smartphones during the lecture and to immediately afterwards answer a short voluntary survey. The sessions were held at two different lectures with different audiences. Both of the sessions lasted for 2 hours and the tests were performed after about 1 hour into each lecture. The first session was held at a course in digital transformation for executives. There were 14 participants in the activity and 11 who responded to the survey. The respondents were in the age groups 25-65, where seven identified themselves as females and the other four as males. The second session was held with university students at a lecture about design methods. 25 students responded to the survey. The respondents belonged to the age groups 17-44, where 13 identified as female and 12 as males.

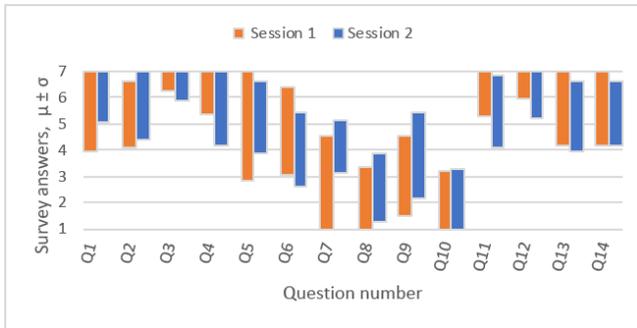
#### 6.2.1 Survey

The survey about engagement consisted of 14 questions based on O'Brien and Toms' model of user engagement. Afterwards, open-ended questions allowed the respondents to give comments about if they perceived any technical issues and also to give general comments. The respondents were not informed that the questions focused on engagement. The questions were unordered in the survey but could be separated into categories based on O'Brien and Toms' threads of experience – sensual, emotional and spatiotemporal engagement.

The questions about sensual engagement were about perception of the information, graphics and technical stability but also about the level of challenge, while the emotional engagement focused on motivation and enjoyment in the activity. The spatiotemporal engagement focused on feedback and social awareness, but also on the time for the activity and the movements. Finally, two questions about the concept itself collected the participants opinions about the energizer and how suitable the activity were for a lecture.

The questions were answered through a Likert scale with seven steps ranging from "Strongly Disagree" to "Strongly Agree". The scale used for the questions was defined as 1; Strongly Disagree, 2; Disagree, 3; Somewhat disagree, 4; Neither agree or disagree, 5; Somewhat agree, 6; Agree, 7; Strongly Agree.

<sup>10</sup> <https://github.com/richtr/NoSleep.js>



**Figure 8. Comparison of results from the two groups participating in the audience test.**

### 6.3 Result

In both sessions, everyone in the lecture did participate in the activity and everyone but three people in the first session responded to the survey about engagement. In total there were 36 respondents to the survey. The questions with Likert scale in the survey were separated into two pages, of which two respondents only answered the first page (Q1-Q6).

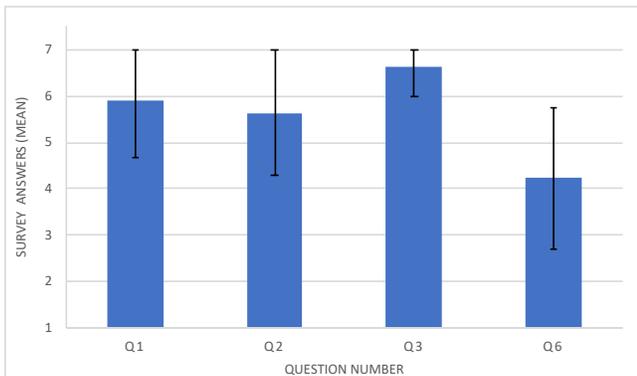
In Figure 8 the results from the two tests can be seen, displayed with standard deviation relative to the means. The result show very similar results for all questions, with the exception of Q7. The data from the two groups was therefore further analyzed together, instead of compared, but with Q7 taken into consideration.

#### 6.3.1 Sensual engagement

To evaluate the sensual engagement, the respondents were asked to respond to the following questions:

- Q1. The design of the interface was overall pleasing
- Q2. The instructions made it easy to know how to perform the activity
- Q3. The activity was overall easy to perform
- Q6. To get a good score was overall easy

Related to sensual engagement were also the technical aspects such as if the screen has been locked or if a user didn't get any score.



**Figure 9. Result from survey for questions about emotional engagement, displayed with mean and standard deviation.**

As seen in Q1 and Q2, the interface was overall perceived as pleasing and the instructions made it somewhat easy to know how to perform the activity. A few respondents wrote that they wanted more information, especially about the score and how to perform the movements, while one instead commented that there were a lot of information in different places and exemplified that information was shown both on the presenter screen and the smartphone. The same respondent also commented that the flow was a bit fast.

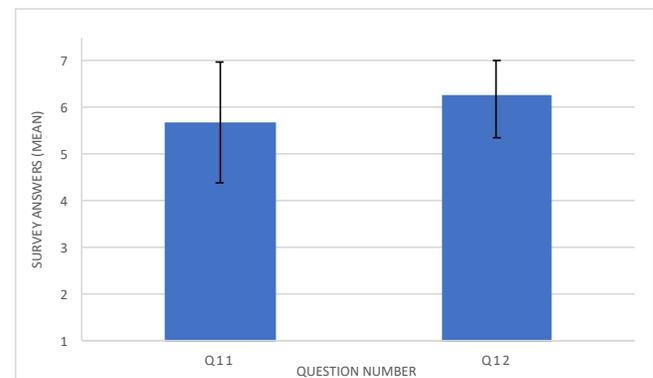
The audience clearly agreed that the activity was overall easy to perform in Q3, but when it came to whether or not it was easy to get a good score the respondents were neutral.

In the aspect of technical issues, two participants reported in the open-ended questions that their screen accidentally locked during the exercise, leading to 0 points in those sets. One participant also reported that he/she got 0 points in one of the exercises for an unknown reason.

#### 6.3.2 Emotional engagement

For the emotional engagement the questions were:

- Q11. I felt motivated to perform the activity
- Q12. The activity was fun



**Figure 10 Result from survey for questions about emotional engagement, displayed with mean and standard deviation.**

In Figure 10, the results for emotional engagement can be seen. The results from Q12 show that the participants agree that the activity was fun, with a mean just above 6 out of 7. In average, the participants also did *Somewhat agree/Agree* to being motivated to perform the activity. In comments several respondents expressed that it was a fun experience and great thing.

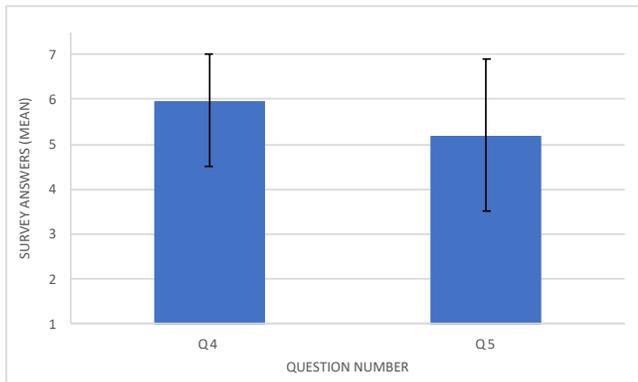
One participant commented that s/he did not appreciate the competition part, and another suggested that s/he would have preferred to compete with him/herself.

#### 6.3.4 Spatiotemporal engagement

The spatiotemporal engagement was evaluated through six questions, where the first two were:

- Q4. Seeing my score in relation to others motivated me to perform the activity

Q5. Showing my score after each movement was a good form of feedback on my performance



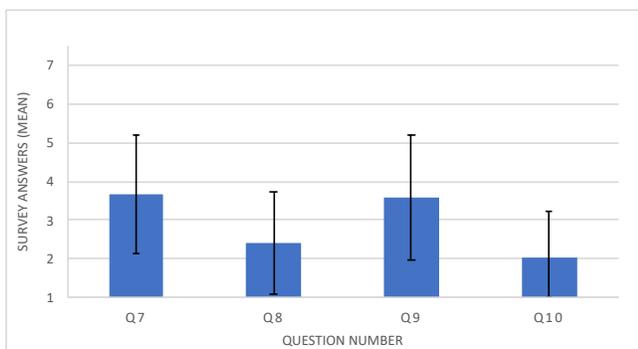
**Figure 11 Result from survey for questions about spatiotemporal engagement, displayed with mean and standard deviation**

The answers in Q5 show that the score was perceived as a somewhat good feedback on the results, and Q4 shows that comparing scores with others was motivating. In the open-ended questions a wish to get more information about how the scores were calculated was mentioned from several respondents. They expressed an insecurity about if the directions of the movements were important for the score and if so, if the direction should be in the same direction, or in the opposite, to the animation. One respondent also asked to get feedback on how to improve your score during the game.

Regarding the grip of the phone one respondent commented that a grip accessory might help to move more freely and make the player score better.

The other four questions related to spatiotemporal engagement were:

- Q7. The time for each movement was too short
- Q8. The time for each movement was too long
- Q9. The time for the whole activity was too short
- Q10. The time for the whole activity was too long



**Figure 12 Result from survey for questions about spatiotemporal engagement with focus on time for the activity, displayed with mean and standard deviation.**

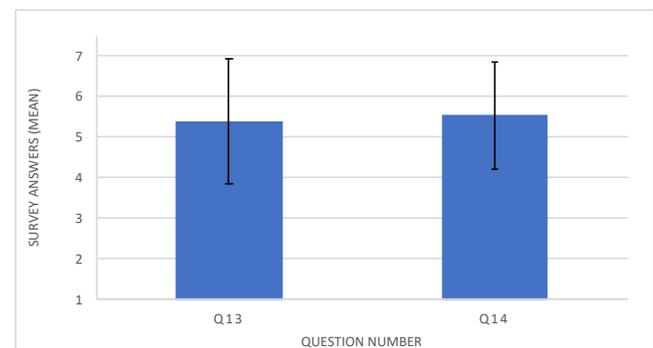
The time for the activity was neither perceived as too short or too long. The respondents tended to be neutral to the statements saying the activity was too short, and disagree more to the activity being too long. Though, the standard deviation shows that there was some disagreement regarding the time of the activity as well as movements. Q7 was the question with the most difference between the groups, where Audience 2 had a higher tendency to perceive the activity as too short.

### 6.3.5 Proof of concept

The final questions were more focused on the concept rather than engagement. The questions asked were:

Q14. The activity made me feel energized

Q15. The activity is suitable as an energizer activity during an educational lecture



**Figure 13 Result from survey for questions about the proof of concept, displayed with mean and standard deviation.**

Regarding the proof of concept, the participants answered *Somewhat agree* or *Agree* when asked if feeling energized by the activity in Q13. In Q14, if the activity was suitable as a lecture energizer, the result was similar to Q13.

## 7 DISCUSSION

### 7.1 Smartphone as motion gesture controller

When developing an activity using the smartphone as a motion gesture controller, it soon becomes clear that the main purpose of the smartphone motion sensors is not to work like a Wii Remote.

First of all, there is a great limitation in what the sensors can actually do. Since they are not capable of knowing their physical position but only acceleration and tilt relative to the ground, there is a great limitation in which types of movements that are possible to recognize and to which level of accuracy. For the proof of concept, a very basic method was used for managing the sensor data, without taking neither direction nor position into account. This seemed to be a partially successful method as the activity overall was perceived positively. Focusing on frequency and intensity of movements seemed to be a good approach for an audience activity. It created a good feedback for simple movements and worked for different browsers and hardware, without using advanced pattern recognition and large datasets, as

previously have been suggested to detect more precise gestures [1].

The second obstacle with using the motion sensors for gesture interaction was the limitations in the native functionalities of the smartphone. In the evaluation, a few users did accidentally lock their phones during the activity. This can be related to the design of today's smartphones, where the large front display with touch functionality makes it difficult to hold the phone without accidentally touching either the display or any buttons on the sides, that could lead to closing the browser tab or locking the screen. With a native application this would have been easier to avoid, since a native application makes it possible to capture sensor data even when the smartphone is locked, or the application window hidden. Though, to develop a native application instead of a browser based would require more development to support different devices and operating systems. It would also require the whole audience to download an application - something that could increase the technical obstacle to use the system and making it harder to use in a real setting.

### **7.2 Feedback and information**

Two important factors for the period of engagement is feedback and control. Even though the activity and competition both were perceived as highly engaging in many aspects, there was confusion around the score. The respondents did somewhat agree that showing the score after each movement was a good form of feedback, but comments showed that there were uncertainties about how it worked. There were especially confusions about what the score was based on.

Since there is no natural translation between movements and numbers, the score gets complicated. In the "Wii like"-games developed by Vajk et al., feedback was provided through visual elements on the screen that corresponded to the tilt of the phone [21]. As the players' movements were translated directly into movements on the screen, this created a clear connection between the input and output. Even though translating movements into numbers is complicated, there are example of games that manage to provide a score as feedback for motion gestures. The difference, is that these games often have very few players on the same screen. This makes it possible to provide real-time scores for each player as well as additional visual feedback on the movements. In the case of this study, the game had to allow for a larger number of players. As the presenter screen can only display a certain number of individual players before it is difficult to distinguish, real-time score and individual visual feedback is hard to achieve for the size of an audience.

To help the user understand the connection between the movements and the score, more information could have been provided. In general, the provided instructions were perceived good enough to understand how to perform the activity, but specific information about the score was requested by several participants. More detailed information

about how to improve or generate a better score would probably make it easier to understand the score and could possibly change the perception of the feedback.

### **7.3 Design of a lecture activity**

The activity was perceived as overall easy to perform, which could relate to the basic movements, allowing for a diverse group of people to participate. When asked if it was easy to get a good score, on the other hand, the participants were of more conflicting opinions, and in general neutral. According to O'Brien and Toms' model of engagement, lack of too much challenge can be a reason for disengagement, which means a neutral result on this question can still be interpreted as positive in terms of engagement. This could also be related to the general confusion about the score and how it worked.

The results from the survey showed an emotional engagement, and the activity was perceived as both fun and motivating. Even though a few people didn't appreciate the competing concept, it seemed to have been appreciated in general and seeing the score in relation to others was perceived as motivating.

To suit an educational lecture, the activity was intentionally made relatively short to avoid taking focus from the purpose of the lecture while still being long enough to be effective as an energizing activity. The length of the activity was not perceived as too long, while a more neutral reaction was expressed towards the activity being too short. The results showed that there might be room for increasing the time of the activity in some parts, and in a future iteration of the design this could have been explored. The activity in general was perceived as relatively energizing and suitable as a lecture energizer, and it would therefore be interesting to further explore whether or not these factors correlates to the time for the activity as hypothesized.

### **7.5 Method criticism**

The idea of using an existing ARS for the implementation came from that the fact that the tool would already be used in the classroom, which would make the setup before starting the activity short and simple. Though, none of the lectures where the proof of concept was evaluated, did really use the ARS during the lecture outside of this activity. This means a longer time for setting up the activity before starting and possibly a different attitude towards the concept. By evaluating the concept in an audience that actually uses an ARS throughout the lecture, different results related to the concept could have been achieved.

In this study, a strong focus was to make the proof of concept diverse, implementable and used in a real setting. This meant adjusting to some technical and interactive prerequisites that were not the most ideal for exploring the interaction itself. For example, to explore the motion gesture interaction isolated, a native application would probably have been to prefer rather than browser-based technology since there are less limitations when developing natively. This would have

led to a more specific result for motion gesture interaction rather than how to implement from a market perspective.

### 7.6 Future work

As the purpose of this study was to explore how to implement and design for smartphone sensors in an audience context, the main focus was not on the concept of the developed game. This is an area for further exploration, and different concepts could be tested. For example, another concept could be to perform the same movements several times during the activity, to allow for the users to better understand how the scores were actually affected.

Feedback from motion gestures in general is also an interesting area for exploration, especially how the movements can be translated into other outputs than visual movements. A study where one group gets sensor-based scores and one gets randomized scores could also be interesting, to evaluate the feedback and if the perception of the score is actually affected by the sensors or if it is imagined.

### 8 CONCLUSION

The purpose of this study was to explore the area of smartphone motion sensors and how to use them for an engaging physical activity within a lecture environment. To do this, a proof of concept of an imitation game was designed and implemented in an existing ARS, and the concept was evaluated with two audiences with focus on engagement.

The final proof of concept was perceived as a fun activity that managed to engage the audience in several aspects, with key elements such as the activity being easy to perform and in competing with others.

The study showed that there are limitations for what can be done with smartphone motion sensors using browser-based technology, both from a hardware perspective but also based on the native functionalities of a smartphone.

When using motion sensors for interacting with a presenter screen for output, the feedback is complicated. As there is no room for individual continuous feedback during the gestures to indicate what is good and not, the gestures have to be translated into something else. A score was a working concept that was perceived positive, but it was important to inform the users how the score translated movements to numbers to fully engage.

When designing for an audience, it is important to create an activity suitable for a diverse group of people but at the same time consider the level of challenge as a too easy task could lead to disengagement. Competition was in general an appreciated concept, and the activity itself was partially considered suitable as an energizing activity during an educational lecture.

Further work could be exploring how the time for the activity affects the energizing effect and the appropriateness in a lecture. Feedback for motion gestures in general would also be an interesting area for more exploration.

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TRITA 2018:577