Lumos Strap: Motivating children's participation in Walking School Bus

Abstract
Walking School Bus involves organizing school children in walking to school in groups, as a healthy alternative to traditional transportation.

However, Walking School Bus have trouble keeping participating children motivated over time. In this project we design a wearable LED shoulder strap, that supports engaging walking-based activities with motion tracking, and audio/visual feedback, while also providing increased visibility for safety. Activities can be initiated when walking in non-safety-critical situations, to enhance motivation for continued participation. The design revolves around a gamification based experience that extends to after walks have ended, while also supporting the existing Walking School Bus system used by Danish schools.

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Process structure

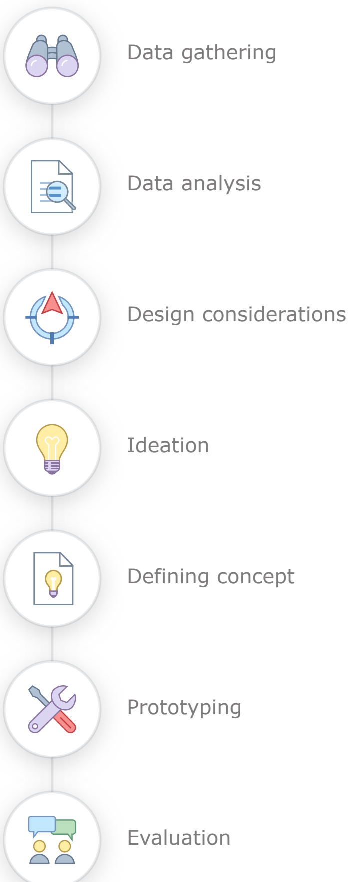

Fig. 1: Summary of our process of work

Introduction

Walking School Bus is an increasingly popular concept that exists in several countries, giving young school children an active start to their day, by walking to school in groups. The groups are usually guided by Chauffeurs, that can be parents, teachers or older children. In Denmark, the concept has been adopted by the organization Dansk Skoleidræt, that since starting the Gåbus initiative in 2012 has helped start up Walking School Bus on 51 schools [2].

Dansk Skoleidræt is a national NGO that promotes health, well-being and physical activity in Danish elementary schools, with initiatives designed to increase activity before, during and after school time, that can be implemented by schools.

The Gåbus initiative consists of a tailor-made concept that can be implemented in schools, to help create walking routes where older children walk with a group younger children to school. The concepts include a website and mobile application for managing the Walking School Bus journey, a chauffeur course, a reward day for chauffeurs, as well as a selection of Gåbus merchandise. The following are the main stakeholders and constellations of the gåbus concept:

The Passengers are children ranging in age 6-10 years. These are the main target group the initiative is designed for since they are considered too young to travel to school alone.

The Chauffeurs are children ranging in age 12-14 years, that are responsible for guiding the younger children to school. They are trained in ‘operating’ the walking bus on a training day, where they are taught practical information, rules, traffic safety and how to manage the younger children.

The concepts also involve a project facilitator - called Tovholder, usually a school employee or parent, responsible for creating routes, recruiting Chauffeurs and ensuring the continued operation of the Walking School Bus.

Additionally, the concept has an application, where the Tovholder can create routes, parents can sign children up as Passengers, and Chauffeurs can check in children, to ensure the parents that the children arrive at school safely.

This project revolves around designing a wearable product, intended to provide added value to the existing Gåbus initiative by Dansk Skoleidræt. Our process of work is summarized in fig. 1

2. Research

As a basis for our work into designing a wearable for Gåbus using several data gathering methods, we’ve collected a range of insights from relevant Gåbus stakeholders, about the challenges it might face as well as opportunities for improving upon the current format.

Our research consists of interviews with three different Gåbus stakeholders, insights from related research about gamification and safety wearable for children, and looking at two different existing products.

In order to synthesize our findings into a number of insights, we made use of triangulation for combining

Kim Henriksen
Gåbus Project Leader
Organizational

Rikke Dahl
Gåbus Tovholder at Gistrup School
School administration

Chauffeurs
Gåbus chauffeurs at Gistrup School
Direct influence in facilitation

Fig. 2: Gåbus stakeholders

several data gathering methods, as discussed by Sharp [9]. This was done alongside the Affinity Diagram method [6], to generate our initial design considerations.

Interviews

We conducted three semi-structured interviews [6] with stakeholders actively involved with Gåbus. The purpose of the interviews was to gather explorative insights.

Each stakeholder, listed in fig. 2, represents a different perspective on Gåbus closely associated with their respective responsibilities. E.g. Kim Henriksen has been project leader since 2015 and responsible for starting up Gåbus on schools who wish to partake in the initiative.

Findings from interviews

The analysis of the interviews presented a number of interesting findings related to several aspects of Gåbus. The most significant finding is how Gåbus generally is really successful the first couple of weeks in action with many attendees and parents seeing the positive effect. However, in many cases, the biggest challenge is keeping the Gåbus alive over time.

Kim Henriksen and Rikke Dahl describe how the transaction cost of effectively using the Gåbus continuously is high, with parents having to adapt their morning routine to fit the Gåbus' time schedule, rather than just driving them by car.

"Suddenly they (Passengers) just stop showing up"
"It might not be as fun as they (Chauffeur) thought it would be" – Rikke Dahl

From the Chauffeur's perspective, it's demotivating to have Passengers participation decrease, causing the Chauffeurs to also become demotivated.

Kim Henriksen suggests that parents often think their children would prefer being driven, when in reality the children often prefer getting to school on their own. Therefore he suggests motivating the children is the best approach.

"In some cases, children decide which car the parents should buy, so they can probably also convince their parents that they want to walk to school." - Kim Henriksen

Our common understanding so far along with inspiration from the interviews, guided us in where to continue with the related research.

Related research

Our focus turned towards gamification as a motivational factor for behavior change and safety for supporting the existing positive aspects of Gåbus. This resulted in a number of research paper discussing these areas.

Summarized findings from the most significant papers

Gamification is defined as the use of game design elements in non-game contexts [3]. Looking further into motivation through gamification, Reiners discuss how a true long-term behavioral change can happen through intrinsic motivation using gamification designed as a journey [8]. The design is to be built by layers that can be *"peeled back and create moments of authentic engagement between the participant and the external*

Fig. 3: HALO Belt worn by a child

Fig. 4: Joust game in action

context" [8]. Amongst other papers, we made use of the general gamification elements presented by Simoes [10] which will be presented in *3. Initial Ideation.*

In the field of safety wearable designed for children, Jutila discusses how a yellow safety vest equipped with sensors is used for digital safety framework for teachers and parents [5]. They conclude that, while the wearable vest is successful for providing safety, behavior and activity-related information, the vest could be more appealing from children's perspective and *"include some gaming and socializing applications in addition to safety issues"* [5].

Exploring existing products
During our data gathering, we have conducted research on existing wearable products related to children's safety and general behavior in different contexts. In relation to finding existing products, we made use of a mood board to collect a number of images depicting products and inspiration in Gåbus oriented products and contexts [4].

Using the mood board alongside brainstorms and sketching sessions [9], we increased our common understanding of the problem area while communicating openly about our findings and ideas.

By now the focus of our understanding was revolved around supporting the safety and the motivational aspect of Gåbus. In the following, we summarize two existing products relating to our initial focus.

An example of an interesting wearable designed for children was the Halo Belt 2.0, see fig. 3, which is a crowdfunded project from 2014. The belt lights up in a specific color and is designed for enhancing visibility and safety, as an alternative to the traditional yellow safety vests. The Halo Belt offers a sleek-looking way of being visible while not being 'confined' to a larger vest.

Amongst products related to motivation and behavior change, we considered how physical games and gamification, in general, could play a role in motivating children (and parents) to continuously participate in Gåbus [8]. An example of a physical game is Johann Sebastian Joust, see fig. 4.

The objective of the game is to be last man standing by 'knocking out' each other. Participants 'joust' with PS Move controllers - having their own controller remain steady, while attempting to make their opponents move their controller. Creating a physical game experience involving the full body, in a simple way, with a single motion sensor, combined with light and audio feedback.

By gathering the findings from our interviews, existing products, and the related research we were able to synthesize our findings into a number of insights using the Affinity Diagram method [6]. These insights act as the basis for our initial requirements, used as guidance towards our final concept of a wearable for Gåbus.

Initial design considerations
Through the process we uncovered various influences, the following are the most important design considerations, as a basis to guide our further work:

Fig 5: A selection of ideation sketches

- The wearable must provide an incentive to motivate children and parents to continuously participate in Gåbus.
- The wearable must not be designed for replacing the Chauffeur's responsibilities.
- The wearable must support some of the existing activities and games along the journey to school.

3. Initial Ideation

With the initial design considerations, our ideation process had established a setting that guided our various methods for generating ideas. Brainstorming initiated the design process, where different ideas within the scope of our considerations were explored and discussed in the group. Possible anatomical areas of a person where wearable technology could be applied were identified to be used for idea generation in our further ideation process.

We then explored a number of possibilities of different electronic components. Ideas explored made it clear we needed a common understanding of current contexts and activities where wearable technology could possibly be utilized. This was done by analyzing and mapping each phase of the Gåbus journey to a visual timeline. To support this exploration, the method of Bodystorm [9] was used to help communicate the discussion of ideas.

Based on our initial design considerations, the ideas and sketches focused on enhancing the motivational factor of engaging in different activities and ranging in being oriented towards individual or social interactions. See fig. 5.

It was noticeable how the contexts identified in the analysis of the Gåbus journey fit in well as a basis for a design. A discussion within the group from the realization of possible context-based activities led to the promising aspect of focusing on context-aware functionalities in the wearable technology that could facilitate this.

Furthermore, our focus during the ideation was aimed towards creating a feedback system which could accommodate context-aware functions. These systems were conceptualized, as different ways of communicating a state of a functionality. We worked with visualization, direction, and duration of the communicative feedback in order to enhance the passengers understanding of the specific functions. To aid this process we created web application tool in Processing, which can animate specific feedback effects, enabling us rapidly iterate on our ideas.

Initially, we aimed at providing feedback by placing a visualization on the backpack of a Passenger using a rain-cover. See fig. 6.

The idea supports the assumption of supporting the Passengers peripheral view aimed at the road/sidewalk, by using visual feedback 'backwards' rather than 'forward'.

Although during a rewatch of the Gåbus promotional video we found that the Passengers might walk at various rows and columns during the journey and that the backward feedback approach might present some challenges because of the dynamic formations of the children.

However, we didn't disregard the visual feedback, but turned our focus towards other types of feedback as support for the incentive to motivate continuous participation.

Fig. 6: Mockups of visual feedback on a rain-cover

As mentioned in *2. Research*, Simoes discuss and present a number of elements that support the creation of gamification system. One of the main features are *"Rapid feedback cycles: Immediate feedback help improve strategy and get a better chance of success the next time"* [10].
Based on this we explored how sound could act as an immediate feedback form. By combining gamification elements as *Repetitive experimentation* and *rapid feedback cycle* with an audible sound effect we might reevaluate the apparent peripheral communication without disregarding the visual feedback discussed earlier. The sound could act as the primary feedback, while the visual is a secondary aspect focused on supporting the social interactions.

Requirements
From the described ideation activities, we found the aspects of context-aware functionalities and the communicational feedback of sound and light interesting as elements to continue with.

These were condensed into a list of requirements, following the template for establishing requirements described by Sharp [9].

- The wearable should provide incentive for motivating children to continuously attend Gåbus.
- The wearable should support a gamification framework related to the contexts Gåbus move within.
- The wearable technology should provide visual and audible feedback cycles.
- System design must preserve the leadership role of the Chauffeur.

4. Conceptualizing - Defining concept

This section describes considerations made towards a final conceptualization of concept for an activity enabling wearable device, based on our previously described research, ideation, and requirements.

Context orientation
In relation to our mapping of the Gåbus journey, we have identified four main contexts the walking bus operates in. Therefore several considerations have been done to ensure the designed concept would be able to fit closely in the current context. A selection of these is listed in fig. 7.

Distinguishing between the different contexts would be an important component of the design. Automated context recognition based on location could be a potential solution

Traffic

The bus is walking in highly trafficked areas. It is critical that the wearable does not interrupt the passengers attention to traffic, but instead enhances the traffic awareness.

Play

The bus is walking in low trafficked areas, where there is opportunity for supporting existing games and playful experiences, to create a more engaging walking experience.

Waiting

Time spent at “bus stops” waiting for other passengers, and chauffeurs checking in new passengers on the Gåbus app. Potential opportunity where activities could be introduced as an extension of the play time activities, or as separate activities that doesn’t include walking.

Arrival

The bus arrives at school and the walking school bus is finished for the day.

Fig. 7

however, proposes some problems since it could potentially undermine the Chauffeur's roles of being in charge. A different solution would be letting the Chauffeurs control which activities should be available at what times.

In our concept, we chose to provide support for traffic and playtime activities. The Chauffeurs are in charge of when activities for the context are deployed and finished, maintaining their natural role as group leaders.

Gamification concept

In *2. Research* we describe how gamification elements can be used to increase motivation and promote positive behavioral change. However, it’s crucial to design the gamification experience as a journey towards a real-life setting in which the game elements can be used [8].

Our design concept incorporates the gamification elements described by Simoes: *Repeated experimentation* [10], *allowing different routes to success*, *rapid feedback cycles,* and *recognition and rewards by parents and other students.*

Continuously participating in Gåbus is awarded with points, while achievements for completing games and activities along the journey are awarded as well. The span of activities are short and points are awarded instantly. Parents can see and manage collected points and achievements through the Gåbus app.

Points and achievements the child or Gåbus collectively gather can be used for Gåbus merchandise, field trips and a range of deals that the school, family or child can make use of outside the Gåbus context.

Form Factor

Based on insights from exploring form alternatives, described in *3. Initial ideation*, we chose to base the physical form of our wearable concept, on the same type of strap used by the HALO Belt mentioned in *2. Research*.

This consists of a reflective strap placed diagonally across in front of the body. The strap has an illuminated light strip that provides an opportunity for creating an ambiguous interface to support visual feedback for activities. Additionally, the wearable supports audio for personal feedback aimed at the child wearing it. Because of the walking context is important that visual feedback is not vital for the activities, to avoid it being overly distracting. However the visual feedback is seen as a secondary feature, that could also enable social interactions between Passengers since the output is easily visible for other Passengers. The audio feedback should be apparent for the Passenger and is assumed less distracting since it does not require peripheral attention.

Design concept visualized

The *“Lumos”* strap is worn by all participants of the walking school bus. The following scenarios describe the concept and different types of interactions.

The Chauffeur can set the context mode to enable either play time or traffic time. See fig. 9.

When *traffic mode* is enabled Lumos glows green and monitors movement. When a threshold is exceeded the belt blinks red, and plays an annoying sound to promote

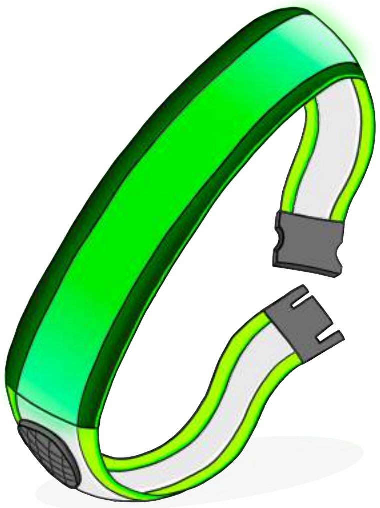

Fig. 8: Illustration of Lumos Strip

walking calmly. Additionally, Lumos can facilitate forming formations to enforce safety, by pairing up gåbus participants using random color schemes, potentially enabling new social interactions by mixing up new walking partners daily. See Fig 10 and 11.

Additionally, Lumos can facilitate a number of play time activities, when activated by the Chauffeur. See fig. 12.

Follow the leader is an example of a play time activity, here a random Passenger is appointed as the leader. The leader then has to do a special movement or walk style. The movement is picked up by Lumos, and the other children have to imitate the gesture of the leader. The correct movement is then awarded positive feedback for both the leader and the other participants.

The activities performed during gåbus, tracked by the gåbus application, so that the Chauffeur can give recognition to the Passenger who performed best.

Additionally, points are rewarded for the parents for further recognition, and to inform what activities their children have participated in during the gåbus.These points can also potentially be linked with a reward system based on the gåbus merchandise store.

With the design concept specified, we can now move onto creating a physical prototype of the concept.

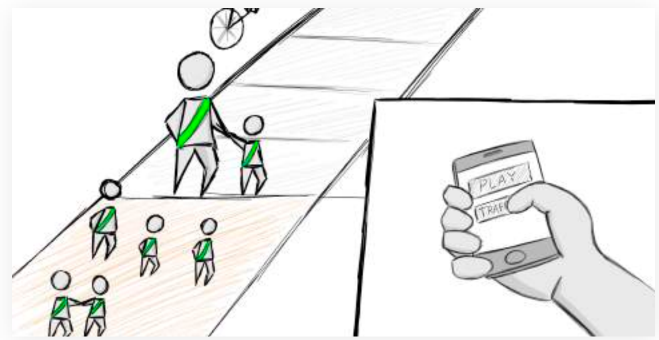

Fig. 9: The chauffeur can set the context mode to enable either play time or traffic time

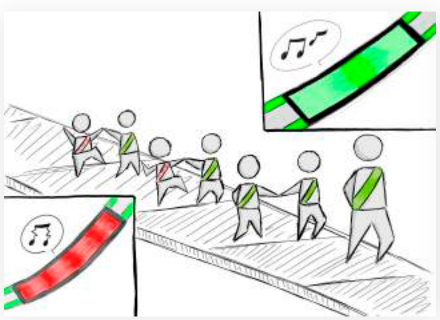

Fig. 10: Positive and negative feedback in traffic context

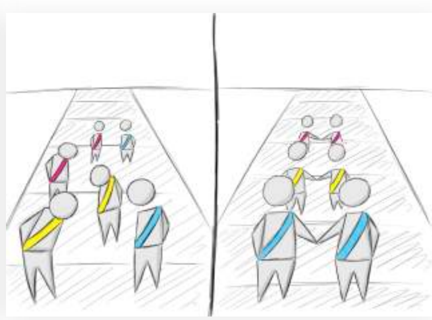

Fig. 11: Pairing up participants using visual feedback

Fig. 12: Follow the leader activity

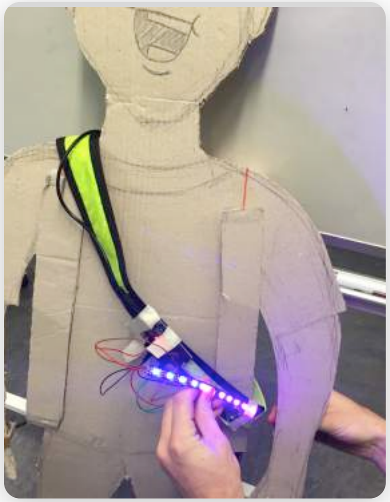

Fig. 14: Initial test of LED’s

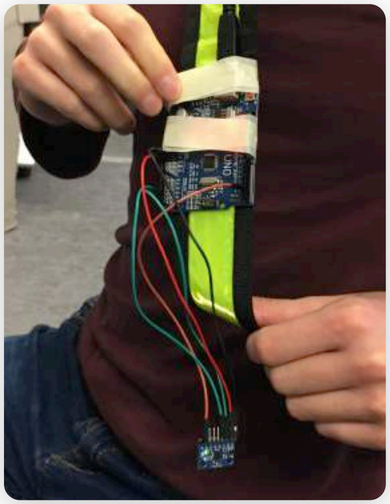

Fig. 15: Test of IMU module placed on body

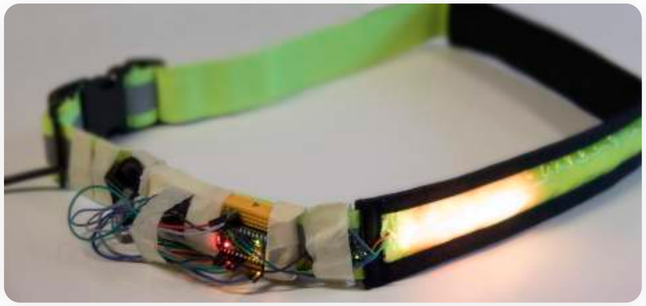

Fig. 13: Lumos prototype showing it’s components

5. Prototyping

This section explains how we constructed a functional prototype of the Lumos Strap. Our product consists of a wearable safety band, with a reflective strip illuminated by LEDs, Arduino microcontroller, IMU, and a mini MP3 module with a speaker. See fig. 13.

Proof of concepts

The first step of our process was to conduct proof of concept tests, to verify that our intended design was feasible. For displaying light animations in different colors, a neopixel RGB LED strip was used. We tested different light animations, intensities, to assess the limits and possibilities as shown in fig. 14.

For tracking movements and motion, the MPU-6050 IMU was used. See fig. 15. The module is an inexpensive sensor containing an accelerometer and gyroscope, which can communicate with Arduino. The sensor was first connected to the Arduino and tested using a Processing-based visualization tool.

The sensor data is intended to be used for tracking movement for activities and games, therefore the raw data had to be converted to usable output. In order to get a smoother less frequent output with reduced fluctuations, we programmed the Arduino to check movement every 20th reading, looking at a calculated average of the most recent readings for both accelerometer and gyroscope.

The acceleration data consists the measured acceleration on the x, y and c axis, which is influenced by the acceleration of gravity. Therefore to register movement we look at changes in acceleration, instead of raw values.

For audio feedback, we used the DFPlayer mini mp3 module from DFRobots. The module can be controlled with the Arduino and provide audio output directly to a speaker.

Construction

The construction of our wearable prototype is based on a LED reflective belt, purchased on eBay. The original electronics and diode were removed to make room for our prototype components.

The original product is illuminated using a single diode, and a flexible diffusing plastic light conductor behind a reflective vinyl sleeve. We replaced this with the programmable LED strip and found the LED’s displayed rather concentrated through the transparent reflective vinyl, which made it difficult to properly achieve the desired visual effect. To create a more convincing effect different materials for light diffusion were tried and tested. Among the different types of paper and foam materials testes, white polyurethane foam proved to be the best material.

The electric components in our prototype are placed on the side of the light strip so that they rest on the shoulder of

Fig. 16: When the passenger walks calmly the wearable lights in a calm green pattern. When the threshold is surpassed the belt blinks red, and a annoying noise is played.

Fig. 17: When the user starts walking slow motion, the light animation changes color, and a progress bar appears. If the user fails to walk slow motion properly, the activity resets. The user completes the activity by walking slow motion for 50 seconds, unlocking a fire animation.

the user. This location is also ideal for measuring full body movements.

For power we used a small rechargeable power bank, that can power the Arduino through a 5v output.

Implementing activities for different context
In our prototype, we implemented the different "modes" to support three different activities during the Gåbus, one for traffic context and two playtime activities.

The *traffic context* mode is for situations where play activities should be discouraged, to keep passenger focused on traffic. In this mode, the wearable compares acceleration movements with a predetermined threshold. This way the wearable can pick up fierce and violent movements, such as running around or jumping. The threshold was tuned to allow for calm movement, occurring when walking. See fig. 16.

The *play time* activities implemented are Elephant Walk and Slow motion walk. In elephant walk, the accelerometer is tuned to pick up hard stamps when walking. When stomping a fun sound is played, and a light animation of a bouncing ball appears on the band.

In the slow-motion Walk activity, the user has to walk slowly and avoid drastic movements. Additionally, the user has to keep turning side to side, walking rotating their body as movement. Accelerometer data is used to monitor a threshold of movement, while the gyroscope data makes sure the user is continuously turning their body. See fig 17.

With a functional physical prototype developed, we could proceed to evaluate it and to gain further insights into the design solution.

6. Evaluation

For evaluating our design concept, a second interview was set up with Gåbus project leader Kim Henriksen to gain insights into how the concept might fit into Gåbus.

Preparation
Prior to the unstructured interview [6] with Gåbus project leader Kim Henriksen, we prepared some material describing our design. A one-page summary of our design concept for motivating children and parents to maintain their participation in Gåbus. In addition, we developed a short video clip that presented the use of the prototype in a trafficked area. The clip showed a simulated Gåbus group walking over a crossroad and how the prototype acted in that context. This was sent to Kim Henriksen, so he could review it before the following interview.

Insights from evaluation
In general Kim Henriksen responded positively to the concept. In regards to the contexts we identified, he validates the assumption that it is possible to introduce game and activities in the Gåbus journey. He weighted that the gamification aspect was the strongest part of the concept, as it has a potential for nudging children into continuously attending Gåbus. He also mentioned that they are already working on exploring how they can create stronger incentives for passenger participation. In relation to these insights, the link between the activities and a larger gamification ecosystem is highlighted as an interesting idea that would fit well into their current

Kim Henriksen
Gåbus Project Manager

"It would be interesting if the chauffeur had a play catalogue. Maybe if they come up with good activities on their way, they could send them in, so it was a sort of interactive sharing of good ideas"

application. Kim Henriksen speculates how this could be expanded with a sharing function between the different Gåbuses. See quote on the left.

He mentions that facilitating games is already a part of the Chauffeur's role, which fits with our concept focusing on having the Chauffeur's control of when games should be available. Additionally, it is noted that it is important that the activities are not too time-consuming, making the gåbus journey longer than necessary, potentially having a negative effect on participation, since time is an important factor in the morning.

In regards to traffic context features, he calls for concern, that the peripheral action might draw the children's attention toward the visual feedback happening on the wearable and away from the traffic and chauffeur's guidance. He mentions the potential of incorporating haptic feedback as an alternative solution and still support the traffic based activities and in the same regard, provide a tool that the chauffeurs can use to get the passengers attention.

7. Discussion

In this section, we will discuss a number of areas we find interesting in relation to our project, our process, and outcome of this.

Scope of the project
One of the main considerations in guiding our work is the finding that parents need the motivation to let their children continuously participate in Gåbus. From this, we assume that to motivate parents, we must engage the children in an exciting experience along the journey.

By the nature of our design considerations, it would have been apparent to initiate an evaluation course with a Gåbus-school. This would have enabled us to continuously evaluate assumptions and gaining insights in relation to any of our considerations, directly from stakeholders.

However, it's important to note, that any evaluation requires some level of sophistication in relation to facilitating, producing and designing the artifact involved. Combined with the difficulty of accessing a functioning Gåbus-school, we decided to keep our focus on using our design considerations appropriately and constructing a working prototype we could evaluate with a stakeholder.

Gamification in general
In our concept, we make use of gamification elements in two areas: Lumos Strap incorporates feedback cycles using LEDs and audio effects. The ecosystem in which Lumos should act is using recognition and awards by other stakeholders.

We assume that these elements play a role in creating motivation toward participance on a longer term. The assumption of using extrinsic rewards to motivate is supported by being able to use the long-term gamification elements in a real-world context – e.g. using points/awards from Gåbus to get free trips for local activities [8].

However, without the evaluation of the wearable and the ecosystem in action, it's difficult to discuss our design choices. Although when looking at related research in areas of technology and extrinsic rewards facilitating intrinsic motivation, the paper by Belim concludes how a possible detrimental effect of gamification towards intrinsic motivation, was discovered during their study [1].

This is supported by Lepper, who generally describes how extrinsic rewards can undermine the intrinsic motivation using overjustification of the rewards [7].

These findings might guide us toward being more careful in designing the gamification elements and incorporating these into an ecosystem. Especially in an evaluation context, where the papers describe the considerations might be more relevant.

Contributions in HCI

When discussing our contribution within the HCI-field, we turn towards the paper by Wobbrock, which lists a number of ways to contribute. Of these, our work is closely related to the artifact [11].

By conceptualizing, prototyping and constructing a wearable we include a new ecosystem for using gamification in Gåbus context as well as techniques for enhancing safety and visibility in high-risk traffic areas. We manifest these within the wearable prototype and with the project report and videos.

Our project can also be seen as an example of research through design [12], where we gain insights in circumstances, challenges, aims, desires, pains, and wishes of the stakeholders in Gåbus. These insights were only possible because of the concrete problem framing provided by the designed artifact.

Future work

It would be ideal to conduct an evaluation of our wearable, with relevant stakeholders. While this is seen in a short-term perspective, further work is also apparent through the evaluation with Kim Henriksen in *6. Evaluation.*

He suggested a way to expand the use of the gamification ecosystem revolved around Gåbus activities: Creating a play-catalog of shared play activities within the Gåbus application system might be of interest in supporting the social and engaging activities within Gåbus.

For future work, we could look into expanding the Gåbus app from the limited perspective of organizing attendance and registering children to Gåbus journeys, to incorporating a community hub. A shared hub where the collaboration of Passengers and Chauffeurs have the possibility to create new play activities, perhaps developed during a Gåbus journey, and describe and upload them for all to explore.

Furthermore, it would be interesting to look at the possibility for implementing the prototype functionalities into such shared play activities, where the users might be able to customize the feedback options available to correlate with their mindset for the individual activities.

Conclusion

We conclude we have designed and developed the concept of a wearable prototype that proposes a solution for the main challenge faced by Gåbus - lack of motivation for parent and child’s continuous participation. As a result of this, we have developed a working artifact with the potential of facilitating further evaluations based on our design considerations.

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