"I had super-powers when eBike riding" Towards Understanding the Design of Integrated Exertion

Josh Andres
Exertion Games Lab RMIT University & IBM Research
Melbourne, Australia
josh@exertiongameslab.org

Julian de Hoog
IBM Research
Melbourne, Australia
juliandehoog@au1.ibm.com

Florian 'Floyd' Mueller
Exertion Games Lab RMIT University
Melbourne, Australia
floyd@exertiongameslab.org

ABSTRACT
The intersection of the physically active human body and technology to support it is in the limelight in HCI. Prior work mostly supports exertion by offering sensed digital information about the exertion activity. We focus on supporting exertion during the activity through sensing and actuation, facilitating the exerting body and the bike to act on and react to each other in what we called 'integrated exertion'. We draw on our experiences of designing and studying "Ava, the eBike", an augmented eBike that draws from the exerting user's bodily posture to actuate. As a result, we offer four design themes for designers to analyze integrated exertion experiences: Interacting with Ava, Experiencing Ava, Reduced Body Control Over Ava and Ava's Technology. And also, seven practical tactics to support designers in exploring integrated exertion. Our work on integrated exertion contributes to engaging in new ways with the physically active human body.

Author Keywords
eBikes; exertion; body; integration; cycling.

CCS CONCEPTS
• **Human-centered computing** → Human computer interaction (HCI) → Interaction paradigms • *Embedded and cyber-physical systems* → Sensors and actuators

INTRODUCTION
The intersection of the physically active human body and technology to support it is in the limelight in HCI (eg. [2, 6, 10]). Most prior work focuses on supporting the user by offering digital information about the user's exertion activities after the exertion activity (eg.[3, 38, 67]). In contrast, we focus on supporting exerting user during the activity through sensing and actuation, facilitating the exerting body and the bike to act on and react to each other in what we call "integrated exertion".

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We articulate our experiences of designing "Ava, the eBike" to investigate integrated exertion between the rider and the eBike – which was studied with 22 riders that hosted Ava for two weeks each.

eBikes are bicycles fitted with an electric engine to provide "power assistance" to the rider [34, 35], who enjoys the experience that eBike cycling affords as they can go further and faster, while enjoying their surroundings and being physically active. This has attracted people that did not cycle to use eBikes, resulting in more people benefiting from being physically active [25, 35]. However, little has been done in terms of exploring how the body of the rider and the eBike integrate to facilitate engaging cycling experiences. We consider the rider's body of great importance as in cycling the body of the rider and the eBike are working together; hence, exploring how the bodies integrate can offer insights for future user experiences.

Today's eBike enhancements mostly focus on technical features, such as longer battery life [66] and mounted display use for way-finding [15, 59], which often result in extra controllers that add complexity to the user experience [34]. In this work we explored facilitating integrated exertion between the rider and the eBike by leveraging the rider's posture while cycling to interface with eBike features, more specifically, by 1. leaning the torso forward to access the eBike's engine assistance to go faster (actuating), and 2. when resuming cycling, going slow and often standing up, activating hazard lights to increase safety. (Fig 1).

Figure 1. Ava senses the rider's posture to activate: 1. the eBike's engine acceleration according to the rider's torso angle. 2. when going slow (resuming cycling) activating LED safety hazard.

Integrated Exertion

By "Integrated Exertion" we refer to systems where the user is investing physical effort as part of an exertion experience (according to the definition of Mueller et al. [51]) and the system can act and react to the user's actions to support the exertion experience. In this case, by sensing and actuating, which might initially sound counterintuitive, as exertion systems have been applauded for supporting energy expenditure [33, 37, 50]. However, we argue that the system can be aware of the exerting user's whole body to interface with mechanical features of the system during the exertion experience, towards facilitating integration between the bodies. This offers new opportunities to engage with the physical active human body and is an emerging area in HCI. As such, our investigation aims to answer the following research question: "*How do we design integrated exertion experiences?*". We address this gap in knowledge by making the following contributions:

- An eBike prototype as a case study for designing integrated exertion experiences.
- Results from a study with 22 eBike riders using our prototype.
- Four design themes for designers to analyze integrated exertion experiences.
- Seven design tactics for designers interested in developing integrated exertion experiences.

Our results can be used not only for future eBike explorations, but also for other actuation enabled systems such as: eScooters [22], eSkateboards [31], Segways [61], eWheelchairs [28, 55], as well as, exoskeletons, (structures worn around the body to support the user's movement) [55] where the user also exerts while the system supports the exertion through an actuation component. Lastly, the proposed themes and design tactics offer an understanding of how to design for integrated exertion experiences, applicable to game designers who want to design for the physically active human body.

RELATED WORK

To design for integrated exertion experience we draw from cycling and technology, whole body interaction and exertion literature.

Cycling and Technology

Sports technology is helping riders cycle faster, through focusing on performance and competition [56, 67]. Other works suggest the online social aspect afforded by technology can promote social interaction and discoverability of other riders' routes [21, 67]. Additional research studied virtual environments, where bikes are fitted with sensors and a screen to facilitate a social virtual cycling environment from the rider's home [13]. 'Pedelecs'[54] are another example of cycling and technology, these are bikes where the rider accesses the engine's assistance when pedalling, rather than using a throttle.

In addition to investigating cycling performance, these works explore how technology can facilitate social interactions and support the rider in novel ways. However, there is limited knowledge available about how eBikes' technology can support riders beyond feature enhancements for the eBike, therefore we believe this is an opportunity to draw from this technology towards designing integrated exertion.

Cycling Safety and Navigation Through Interactive Technology

Researchers have also explored assisting riders in way-finding and cycling safety: for example, Dancu et al. [15] explored the use of projections while cycling for navigation and safety. Walmink et al. [65] experimented with a head motion controlled LED helmet to increase safety when turning and braking. There is also an increasing number of crowdfunded bike products that combine cycling and technology in novel ways: Smarthalo [14] functions as a GPS, night light, and SpeedX Aero Leopard [43] includes heart rate, cadence and speed statistics to inform the analysis-focused rider. These works explore bike interactions to support safety, experimenting with gesture and body movement control.

Experiential Aspects Of Exertion And Cycling

Other works have focused on the experiential aspects that exertion and cycling can offer. For example, Rowland et al. [59] have explored mobile phone-based app experiences for cyclists using GPS and concentrating on the enjoyment of cycling. Their conclusion is that, "[bike] design has to respect the distinctive nature of cycling as a mode of transport and needs to carefully interweave moments of interaction with it." Bolton et al. [9] combined virtual reality and an exercise bike to simulate users cycling down a virtual street while throwing newspapers which resulted in an immersive exergame. In the classroom, exertion and cycling have also been explored to support learning [1], using the bike as an input controller. These examples approach exertion and cycling from a *ludus* perspective offering structure to players in the experience. However, designers can also approach exertion and cycling from a *paidia* perspective, focusing on improvisation and unstructured play [46], for example: Landin et al. [42] combined sound elements with cycling on their "iron horse", which is a bike that makes horse-like sounds when cycling. The use of LEDs in the spokes as a way of supporting creativity and self-expression has also been explored [29].

These works highlight that technology can also support the experiential aspect of cycling and exertion. Despite the fact that cycling seems to offer various benefits, little exploration has occurred into the use of technology to design for supporting the experiential side of cycling, which this paper aims to contribute to.

Whole Body Interaction In Exertion Games

Focusing on whole body interaction in exertion games teaches us that limiting screen feedback during the exertion activity can facilitate players to remain focused and more in tune with their bodies, which in turn, can improve the user experience [53]. This has led others to explore player feedback beyond the screen and directly on the body, such as using galvanic vestibular stimulation electrodes connected to the user's mastoid bone behind the ear to facilitate sensations of pulling or swaying as player feedback [12]. Maeda et al. [47] combined this approach with music, synchronizing rhythm and feedback intensity to create an entertaining experience. In this line, electrical muscle stimulation has been used in mixed reality games to offer player feedback according to their whole body interactions in the game, such as, offering a counter force by actuating and causing the user's arms to repulse when touching a virtual force field [44].

These works highlight means of providing feedback directly on the user's body within the context of the experience and facilitate novel whole body interactions. Resulting in players moving freely and focusing on the experience. To this end, this area offers opportunities for exploration in particular when it comes to exertion experiences, as little has been done to support the exerting body during the experience.

Experiencing Our Body In Whole Body Interaction

When it comes to experiencing our body, we learn from 'body schema' which refers to: "*our nonconscious knowledge of our lived body and of our potential for bodily actions in the world"* [63]. For example, when a rider uses an exertion system, such as an eBike, their body schema extends to include the eBike as an extension of their body during cycling, the rider can sense aspects of the ground through the eBike's body [5]. To this end, we wonder what the extended body schema means for designing integrated exertion experiences and how the rider can integrate their body with the system to interface with mechanical features of the system.

Human-Computer Integration

Farooq and Grudin recently took a stance beyond human-computer interaction to state that human-computer integration "implies partnership [where] partners construct meaning around each other's activities, in contrast to simply taking orders" [23]. Early exploration of "integration" has begun by looking to integrate the human body with technology in "superhuman sports" [40], from which intriguing user experiences can be facilitated through sports activities referring to the Paralympics, and also novel exertion games [32]. We believe that "integration" presents opportunities for designing integrated exertion as the rider and the system could be working together in partnership towards an engaging exertion experience - which has led us to consider how an actuation enabled system such as an eBike can construct meaning from the rider's whole body during exertion.

AVA, THE EBIKE

Ava uses the rider's body in two ways: 1. As the user leans forward as a result of trying to invest more physical effort such as when aiming to cycle faster or climbing a hill, or embracing speed when going downhill. The angle of the rider's body as it leans forward serves as a control mechanism to activate the electrical assistance and go faster. As the rider leans forward and the eBike accelerates we built in an acceleration sound to amplify the sense of acceleration, which can be turned off if desired. 2. As the rider stands up to pedal to resume cycling, Ava activates LED hazard lights to make nearby vehicles, bikes and pedestrians aware of the eBike, thereby contributing to the rider's safety.

Why leaning and standing up?

We chose to experiment with these three features because:

1. leaning forward to accelerate enabled us to explore a more integrated and physically engaged experience when the rider accesses the assistance beyond using throttles, as throttles only require a twist of the wrist. We noticed in our previous study [2], that riders usually lean their body forward to embrace speed in cycling. This also occurs in different sports, such as surfing and skating, and this led us to explore the rider leaning their body forward so that Ava gradually accelerates. Leaning is an alternative to using the throttle, and could contribute to helping the user remain focused on the enjoyment of cycling rather than on operating controls.

2. the sound plays a key part in the sensory experience of the rider, and so we used sound to support fantasy aspects of accelerating. This is similar to how the wind becomes louder in the rider's ears when cycling faster, and also similar to the changing sound of accelerating mechanical vehicles such as cars and motorbikes. We wanted to leverage this sensory experience to amplify the sense of acceleration with an acceleration sound.

3. we wanted to enhance safety when resuming cycling. eBikes are often slightly heavier than standard bikes and when the rider resumes cycling while standing up to pedal, they can become "wobbly" [34]. Ava takes into account the speed of the eBike and the rider's posture to interpret this as "resuming cycling" and activates LED hazard lights located on the sides of Ava's body.

These three features emerged from our previous work [2], which focused on implementing the system - on this paper we focus on studying the system.

AVA's Technical Aspects

We modified two eBikes (a cruiser and a hybrid) with the same functionality in order to offer participants a choice between eBike geometries and also to accommodate for a wider range of body sizes. These two models offered a familiar architecture to modify and very low motor noise.

Ava Cruiser is built around an original "Dillenger" brand eBike, model OspreyLight, with 250W nominal power [18]. We used a Raspberry Pi 3 Model B as a processor to augment Ava. Riders can accelerate by a) using the throttle or by b) leaning forward. The angle of the leaning posture determines the intensity of the power applied to the motor; the leaning forward is designed so that riders bodily accelerate momentarily, however they can remain in this posture to enjoy acceleration to the fullest. The bodily acceleration angle is calculated with a mobile phone gyroscope sensor worn tightly on the rider's chest, this is placed in a custom made elastic pouch. The gyroscope is calibrated upon turning on the system and it records the current posture of the rider as the rider sitting straight and not yet leaning - users of Ava were briefed on this intialisation procedure. The gyroscope sensor data is interpreted by an Electronic Control Unit (ECU), which uses the data to control both the power assistance and the emitted sound through the speaker. For safety, when leaning forward, one linear hall effect sensor is mounted on the eBike's handle bar to detect handlebar displacement, so that when the rider is sharply turning, bodily acceleration is disabled. Two hall-effect sensors were used to detect when riders are resuming cycling from a stop position: the wheel and pedal rotation detection are achieved by mounting the sensors on the pedal system and front wheel. Ava has LED that pulsate as hazard lights when the rider is resuming cycling (Figures 2 and 3).

Figure 2. Ava Cruiser & Ava Hybrid.

Ava Hybrid offers the same functionality as Ava Cruiser, but we used the Dillenger "Easy step over" model [19]. Ava Hybrid's performance frame offers a sporty look and feel, although it provides the same 250W nominal power.

We designed our system to harness the eBike's battery power (avoiding the need for additional power sources and cabling). We used Ava's Cruiser voltage (28V) to power the LEDs (12V), sound (5V), and main board (3.3V). DC-DC step down converters were needed to achieve the required voltages. This power system was also used on Ava Hybrid, however it offered 42V, therefore we had to use a one buck converter to match the voltage stream down to 28V.

Figure 3. Ava Cruiser & Ava Hybrid offered the same functionality – hardware differences shown above.

STUDY

To answer the research question "*How do we design integrated exertion experiences?*" we conducted the following study towards understanding the user experience of cycling with Ava.

Once participants accepted our invitation, they chose which eBike they preferred to use, Ava Cruiser or Hybrid. We first showed participants how to adjust the phone in the pouch and the eBike seat for their comfort. We conducted a study with 22 eBike riders in the following manner:

1. Participants took the Sports Climate Questionnaire (SCQ) in relation to their eBike. This questionnaire was chosen as we hoped it would give us insight into how Ava might affect the user's perceived autonomy support [16].

2. Participants hosted Ava for two weeks at their home and noted down thoughts about their experience so that these notes could be used in the semi-structured interviews to reflect about their time with Ava. Participants repeated the SCQ in relation to using Ava after the two weeks.
3. Semi- structured interviews were conducted at the end of the two weeks in regard to the rider's experiences

Participants

We recruited 22 participants (F=10, M=12), aged between 24 and 55 (M=36.4, SD=9.4) from a medium size city in the Asia Pacific region. Participants were recruited through both emails and advertisements. Participants came from the university (7), from the local council (8), and from amongst colleagues (7). All participants had been eBike riders for between three months and three years as shown below.

Number of Participants	eBike cycling experience
10	3 - 6 months
7	7 - 18 months
5	19 - 36 months

Table 1. Participants' eBike cycling experience.

Data Collection

Firstly, we collected participants' responses to the SCQ, which has six questions, each with a seven-point Likert scale, where 1=strongly disagree and 7=strongly agree. The two-phase questionnaire is shown on Table 2. Secondly, we conducted semi-structured interviews following Kvale [41] approach, the semi-structured interviews were audio recorded.

Data Analysis

We employed a thematic analysis approach to the data [11]. The interviews were transcribed for qualitative analysis, where two researchers independently consulted their own copy of the scripts. Each researcher created their own codes to capture and group points that were interesting using the Nvivo software. This was followed up with multiple meetings where the researchers viewed each other's codes, refined their analysis and reached consensus in the final codes. For the questionnaire, the answers for the participants' own eBikes and for Ava were charted (Fig 4). The SCQ was used not to reach statistical significance, but rather to paint a comprehensive picture complementing the interviews. The chart, codes and transcripts facilitated the researchers' derivation of the main themes.

RESULTS

We now articulate the results. Participants' names have been changed for privacy. Figure 4 shows the participants responses to the SCQ questionnaire for their eBike (Mean=4.4, SD=0.4), and for Ava (Mean=4.9, SD=0.6).

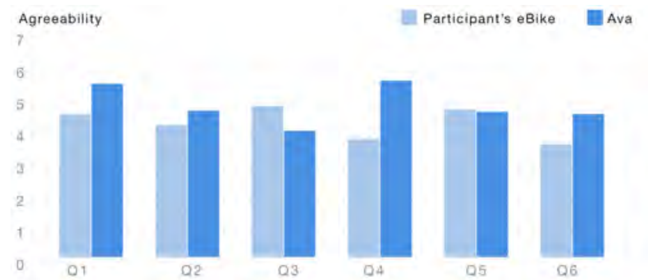

Figure 4. Participants' questionnaire answers.

Q1	I feel that my bike provides me with choices and options.
	I feel that Ava the eBike provides me with choices and options.
Q2	I feel understood by my bike.
	I feel understood by Ava the eBike.
Q3	My bike assists me in feeling more confident in my ability to cycle.
	Ava the eBike assists me in feeling more confident in my ability to cycle.
Q4	My bike encourages my curiosity when cycling.
	I feel Ava the eBike encourages my curiosity when cycling.
Q5	My bike responds to how I would like to cycle.
	Ava the eBike responds to how I would like to cycle.
Q6	My bike appears to understand how I cycle before suggesting how to ride.
	Ava the eBike appears to understand how I cycle before suggesting how to ride.

Table 2. Reworded SCQ questionnaire questions.

Themes

The themes offer things to think about for researchers when aiming to analyze integrated exertion experiences. We note that upon reviewing the codes there were no differences in the results between the two eBikes.

Theme 1: Interacting with Ava

This theme is divided into two categories: 1. Cycling Ava was engaging. 2. Ava supported "natural" interaction.

Cycling Ava was engaging

Overall, participants said they thoroughly enjoyed cycling Ava. Participants exerted themselves while cycling, and used their entire body as afforded by our design. They applauded the system for providing them with an engaging experience. For example, Carl said Ava was *"exciting"*, and Tilly said: *"I felt pretty good cycling Ava"*. While Lisa said *"I felt it was a pleasant and simple way to accelerate"*. In Q1 participants scored Ava higher than their own eBike when it came to how they perceived that Ava provides them with choices and options. This appears to support the rider's autonomy and their engagement with Ava.

Ava supported natural-interaction

It appears that Ava was able to support a more natural-interaction by taking advantage of in-cycling actions, such as leaning forward when wishing to go faster. This seemed to allow participants to access the assistance of the engine while remaining focused on the cycling experience, rather than using a manual controller, for example, Maria mentioned: "It is like when you drive a car, you know how to change the gears, and as you become more experienced and familiar with it, you do so automatically without even looking or thinking, as if sensing the revs of the car triggers you to switch gear, this can be an enjoyable experience." While Byron said: "When I was learning to use my eBike, I would get caught up with some of the controllers like adjusting the speed assistance threshold when cycling, when learning to cycle with Ava I didn't have to think about controllers, that's a good thing". These comments align with Q6 in the questionnaire where participants rated Ava higher than their own eBike. The leaning forward appears to offer more physical engagement than using a throttle and is also an enjoyable way to access acceleration.

Theme 2: Experiencing Ava

This theme is divided into three categories: 1. Ava was more experiential than participants' eBikes. 2. Ava facilitated make-believe. 3. Cycling Ava felt like performing.

Ava was more experiential than participants' eBikes

Participants reported that they found Ava to be more enjoyable than their regular eBikes. For example, Rob described Ava as "more fun" than his regular eBike, and Maria explained that "It was fun using my torso to accelerate". This more enjoyable experience appeared to stem from the fact that Ava was considered "less serious" than a regular eBike. Carl commented: "You see, I think about my eBike as a tool to help me get places, but Ava is more like an experiment and because of that seems more enjoyable". This finding is echoed by the questionnaire results: participants reported in Q4 that they have found that Ava supported their curiosity more than their regular eBike when eBike cycling. We believe this contributed to participants' experiences with Ava being more experiential.

Ava facilitated make-believe

Participants reported that they felt that Ava was able to facilitate a sense of make-believe. For example, participants described that when they experienced the engine power that Ava offered by accessing it with their body, it appeared to facilitate the feeling of a "super power". Lisa said: "When using my torso, it's is like the power comes from my leaning, and not from the engine, it makes me feel stronger". This "super power" seemed to facilitate a sense of make-believe. Tilly reported that Ava allowed her to imagine what it would be like to be in a motorbike race: "I like that the power is always there for you, sometimes when the road is fairly empty, I like to use the body acceleration and take the curves exaggeratedly as if I was motorbike racing". In Q4 participants scored Ava higher than their own eBike in terms of supporting their curiosity when eBike cycling, this probably contributed to participant make-believe moments as they appeared to have been more aware of their surroundings, their whole body, the acceleration and the sounds than when cycling on their own eBike. It appeared that the sound Ava made when accelerating supported this notion of make-believe. For example, Tilly said: "This [the engine power] was particularly fun when using the turbo sound". Jessi commented "When I was accelerating to the fullest it reminded me of the tron motorbikes, you go low to go fast". Participants created moments of "make-believe" [17], as known from games, where the exaggeration in taking the curves while eBike cycling appeared to support moments of fun fueled by a fantasy aspect.

Cycling Ava felt like performing

Participants reported that cycling Ava felt like "performing" when other people were around. For example, Jessi experienced that others were watching her as she tried out the leaning forward acceleration, and she felt like showing Ava off. Jessi said: "There is a flat open space where the museum is, when I was accelerating with my body, and the sound came on, people nearby were like, what is that? I kept showing Ava off". This suggests to us that the environment together with Ava, facilitated entering a performative mode.

Theme 3: Reduced Body Control Over Ava

This theme relates to participant discussions about experiencing reduced body control momentarily over Ava.

Experiencing reduced body control over Ava

The eBike's gyroscope did not consider steep inclination of the road and as a result responded sometimes differently to what participants expected. For example, Lisa said: "I tried a couple of routes with Ava to experiment, I enjoy at times when the leaning forward to accelerate going uphill does not kick in as it made me work harder". Lisa's quote suggests that the inclination of the road when going uphill meant that the rider's attempt to lean forward to get the extra boost was not recorded. However, Lisa thought the eBike's failure to accelerate when on the steep hills was a design feature to push her towards higher exertion and to gage her strength. On the other hand, Carl mentioned: "From my house there is a down hill road towards the park, the first times I was conscious of the increased speed and tried to slow it down, however, over the next times I tested it [Ava] I let the speed increase to see how fast I could go". This suggest that the inclination of the road when going downhill was interpreted as an intense leaning action, causing the eBike to accelerate, even though the rider did not intend this extra acceleration, to this end, participants could use the breaks which switched the acceleration off. In relation to these experiences, Q3 in the questionnaire suggested that participants felt more confident about their ability to cycle with their own eBike than with Ava. This score may have resulted from some of them experiencing momentarily reduced body control as they were getting used to Ava. Participants experienced discomfort and thrill because the experience of reduced body control momentarily over Ava appeared to "disconnect" their body from Ava's, at which point they were conscious of Ava as an object that facilitates cycling – in line with what Heidegger [30] refers to as Ready-to-hand, where the participant is cycling in harmony with Ava, while in control and not aware of Ava as an object. In contrary, when Ava momentarily takes over, the participant experiences Ava as Present-at-hand, where Ava is seen as an object disconnected from their body and no longer moving in harmony, resulting in the rider's attention shifting to Ava from the experience that eBike cycling affords.

Theme 4: Ava's Technology

This theme relates to participant discussions concerning the digital and physical technology we used to implement Ava.

Suggestions for Improvement

The most common suggestion related to the charging of the extra mobile phone, and the second most common was the putting on of the elastic pouch that held the phone, because participants were required to loop the stretchable material around their chest. Tilly commented: *"It is not terrible having to put the pouch on, I know its a prototype, but on a real product I would expect the sensors to be embedded on the helmet or rider's jackets, I take very few steps to unlock my eBike to go, any extra steps should give me a lot more functionality."* It appears that putting on "wearables" in the form of cycling clothing is a limiting factor towards enjoyment that the design of augmented eBikes needs to take into account.

As probably with any bike, people also encountered challenges. For example, Hector found Ava intriguing, however, he had also trouble due to his height: *"I appreciate the extra boost Ava has in comparison to my eBike, especially when taking off, the body leaning forward is interesting, however for my height (1.92cm) and the size of the eBike frame I found it hard to use."*

Hazard lights were not mentioned often

Probably because the lights were more for other people than the rider him/herself, the LED hazard lights did not seem to elicit too many responses from participants. For example, Carl, said: "The LEDs did not do much to me." To gather further responses about the lights, we perhaps should have also interviewed other road users.

DESIGN TACTICS FOR DEVELOPING INTEGRATED EXERTION EXPERIENCES

We now discuss ways of designing integrated exertion experiences based on our craft knowledge of creating Ava. Our experiences of experimenting with Ava and the data collected from the study has helped us refine this knowledge. We present seven design tactics aimed at providing designers with practical guidance when designing integrated exertion experiences, especially to facilitate super-power like experiences.

Tactic 1: Support Rider Autonomy By Allowing The Rider To Choose When And How Much Assistance To Access

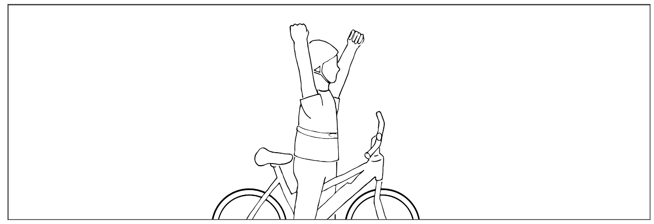

Figure 5. The rider controls when and how much assistance to access, this supports their autonomy during the exertion experience.

With Ava, the rider is always in control of the assistance and can choose when and how much to access. In contrary, with pedelecs or with some exoskeletons, the user does not have the same amount of control, because, as they get on the pedelec or wear the exoskeleton, the assistance is active throughout the experience. In themes 1 and 2 participants highlighted that they enjoyed controlling the assistance, and it supported their curiosity to ride, as well as offering them an engaging experience.

We draw from embodiment to further describe what made eBike cycling with Ava an engaging experience: 1. the rider's bodily and eBike awareness, 2. the environment, 3. their cycling skills and assistance control available, these aspects offered the rider opportunities to be in the world [20]. Examples include cycling a windy road by moving their torso exaggeratedly while using the turbo sound, or racing others and using their whole body to lean and control the acceleration to go faster. This capacity to control and explore supports the rider's autonomy and contributes to the enjoyment of the experience [60].

In practice, this tactic can be applied to the design of integrated exertion and playful experiences where there is a focus on whole body interaction. The user can experience their body in new ways augmented by technology, discovering their surroundings, while gaining bodily-knowledge towards controlling the system as their own bodily super power.

Tactic 2: Promote More Natural-Interaction With The System, Higher Physical Engagement And A Higher Sensory Experience For The User With Ongoing Actions

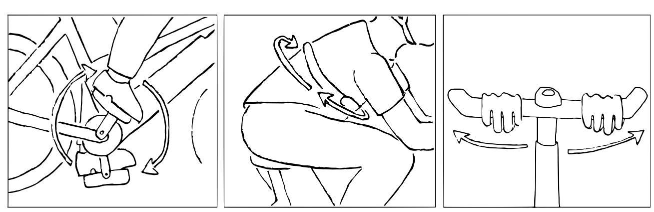

Figure 6. Leveraging ongoing actions to interface with the system's mechanical features promotes natural-interaction.

With Ava, the way in which the rider accessed the assistance was by leaning their torso forward. This movement is often used to embrace speed, and was chosen since moving the torso in cycling is an ongoing action as it is a recurrent movements in the experience [27]. As a result the recurrent movement facilitates the user to build muscle memory and can promote ease of interaction with the system. In theme two, participants reported that leaning their torso for accessing the assistance appears to offer more natural interactions with the system, than using a throttle. Also in theme two, participants highlighted that leaning to access the assistance can offer higher bodily engagement, which in turn affords a higher sensory experience to the rider when leaning to access the assistance due to their body schema including the eBike [5].

We could have used a foreign movement to accelerate, such as spreading the legs, but this would not offer the rider the opportunity to draw from their previous cycling experiences; nor would it tap into their muscle memory. Considering the ongoing actions and feature purpose to map to, are important details of the user experience which when mapped can promote or hinder integrated exertion between the user and the system.

In practice, this tactic can be used to design novel human-system augmentations in super human sports [62], or exertion games [52], by reflecting upon the ongoing actions performed by a player within a game context. This reflection focuses on identifying the ongoing actions within the game context towards integrating supporting technology into the ongoing actions. In this case technology facilitates the player new opportunities to interface with the system while remaining focus on the game experience.

Tactic 3: Design For Zero Body Disparity To Facilitate The Rider To Be One-With-The-System

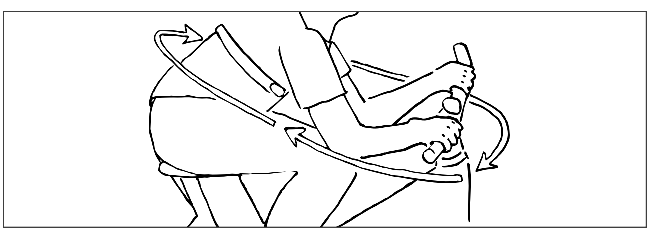

Figure 7. The rider uses their whole body to control the actuation and experiences the sensation of acceleration during eBike cycling.

This study with Ava considered the use of the whole body to physically engage with an actuation enabled system. By design, we considered physical disparity which refers to the distance between the user's input and the systems output [26]. For example, the distance between a laptop's touch pad where the user inputs and the resulting movement of the cursor on the screen where the user can acknowledge the output is 20cm. An important aspect is that the acknowledgement of the output is often through eye sight in screen-based systems, such as laptops, desktops, tablets, smart phones, and also on gestural interaction systems such as on Wii and Xbox Kinect.

In Ava's case, the distance between the user's input by leaning, and the system's acceleration output is zero body disparity. The reason for this is that the user can experience the sensation of the output instantly and directly through their whole body, this appears to facilitate users to experience their body as play [26]. Inline with facilitating player's to experience the output instantly and directly through their whole body as a result of their whole body interactions, are mixed reality games that utilize force feedback [45]. This allows the player to interact with the environment using their whole body, as well as experiencing their whole body as play when experiencing the feedback.

In practice, to design for zero body disparity, designers can focus on whole body input and facilitating instant and direct sensation on the player's whole body as a result of their interactions. This appears when controlling a system's assistance to give the player the ability to control it as if it was part of their body. It also frees the player from attending to alerts, scores and notifications on a screen.

Tactic 4: Fine Tune The Assistance Response To Be Gradual Yet Strong To Offer A More Enjoyable Experience

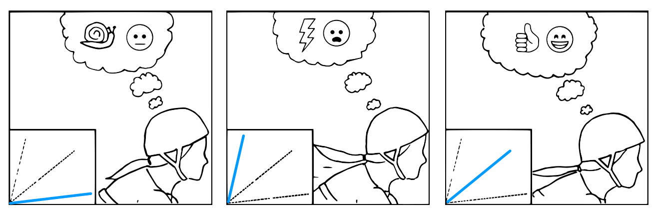

Figure 8. The system's response intensity to user's interaction can yield different experiences.

When evaluating the assistance response from the system, we fine tuned by trial and error, conversing about our experiences after trying out Ava. When Ava responded too strongly by supplying a high amount of assistance with minimal leaning forward, it made the experience feel jerky and uncontrollable. Conversely, when Ava responded with minimal assistance as the rider was leaning forward, it brought the perception that the battery was either low, or the engine assistance was weak. For this reason, we experimented by fine tuning the response to be above medium, where the system is perceived as strong, yet has a gradual progression of response as the rider leans forward - this we believe can contribute to the user perceiving the power to be under their control, and hence it is their super power.

In practice, fine tuning the system's response to the user's bodily movement during the experience can be used as a way to communicate and facilitate different sensations to the user according to the situation. For instance, this tactic can be used in mixed reality games that use Electrical

Muscle Stimulation [45] where the user experiences the sensation directly on their body according to their whole bodily movements.

Tactic 5: Consider Amplifying any Sensation by Engaging other Senses to Facilitate Make-believe

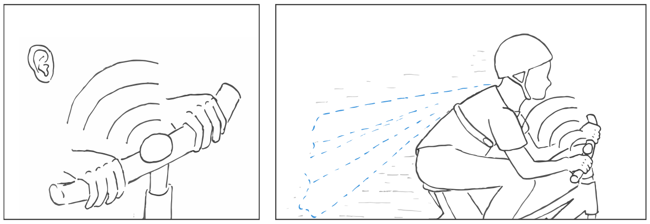

Figure 9. Illustrates a make-believe moment where the rider imagines he has super powers as a result of the amplified sense of acceleration facilitated through audio.

The use of sound allowed riders to amplify the sensation of acceleration as they leaned forward. In particular, the "turbo" sound was quoted often by participants as they enjoyed how it complemented the experience of accelerating. We could have not used sound or chosen a sound that was not complementary to the acceleration. We believe that the turbo sound working in sync with the acceleration was an important aspect in facilitating make-believe moments [8, 17], as reported in theme 2, because it amplified the sensation of acceleration while the rider was leaning forward.

In practice, we learn from other works that engaging other senses in the experience towards amplifying the user's sensation [36, 58] can contribute to the user's experience, for example by igniting performance moments and enjoyment aspects during exertion. Designers can consider engaging with other senses towards amplifying the user's sensation, as this will also contribute to super power like experiences.

Tactic 6: Offer Momentarily Reduced Body Control Without The User's Goals In Mind (Thrill And Discomfort)

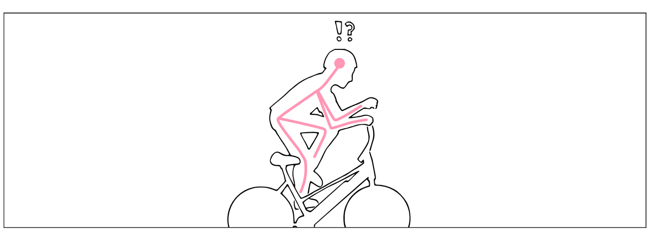

Figure 10. The user can experience their body being disconnected from the system momentarily during exertion.

We learnt in theme three that when the rider was climbing uphill and wanted to use the electrical assistance, but this was withheld, this was considered a feature designed to challenge the rider's physical limits. When the assistance came on by itself as the participant was going downhill, the participant reported feeling discomfort the first times and after a few times, decided to let go momentarily to embrace the speed. We know that thrill and discomfort can be conducive to excitement and enlightenment [4, 48, 49], and in this case resulted in the rider gaining a new perspective of their strength.

In practice, momentarily reduced body control without the user's goals in mind, occurred with Ava because participants did not expect the response in the up hill or down hill cases. This element of surprise facilitates the rider to make a decision on the spot, to either continue with the discomfort and overcome it, or regain control by using the brakes, or getting off the eBike and terminating the discomfort. This notion of reduced body control over the experience has been used in mixed reality games that draw from thrill [39] to facilitate engaging and memorable experiences. Reduced body control over the experience appears to us an important design resource as it can engage the user's whole body within the experience. However, we note that in integrated exertion as most likely users will be moving, offering users the option to regain control will allow them to negotiate the discomfort in their own terms, which in turn, allows them to test their own comfort boundaries and experience thrill.

Tactic 7: Offer Momentarily Reduced Body Control With The User's Goals In Mind (A Sense Of Working Together)

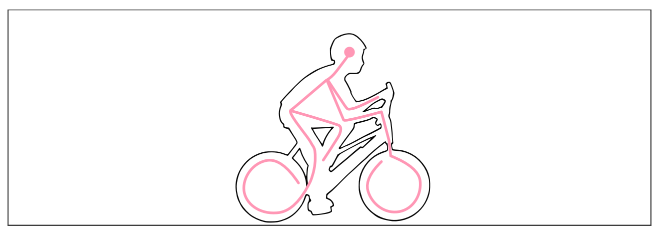

Figure 11. The user and the system can work together by acting and reacting on to each other's actions.

In contrary to tactic 6, in this tactic, the rider expects the system to momentarily take over, resulting in momentarily reduced body control towards the rider's benefit.

For example, the cyber-physics pedelec [64] accelerates when pollution ahead is high towards reducing the rider's breathing rate so that the rider does not need to breath with high intensity in polluted areas. This appears to augment what the user can do, and therefore it can be seen as a form of super power. We believe that this notion of collaboration between the user and the system contributes to the research agenda of human computer integration [24], as it taps into the partnership dynamics when working together and constructing meaning from each other's actions. Furthermore, in the cyber-physics pedelec example, the system can draw information (pollution levels ahead) about the environment in which the user will interact with the system towards supporting the experience. By gaining this knowledge inaccessible to the user senses, the system can act and react not only to the user's actions but to aspects of the surroundings which can benefit or hinder the experience. This approach serves to further the design of integrated exertion, as it can offer functional applications as shown here, but also playful applications. For example, by adjusting the assistance offered when competing with another player according to their bio signals to even out game play or by using information about the environment to adjust the assistance and the user's exertion input to maintain a challenging pace regardless of the inclination.

In practice, designers can consider extending the user's capabilities in the experience for functional and playful outcomes. To further enhance the partnership between the user and the system, the user should know how the system will manifest when participating in the experience with the aim of promoting a sense of trust and collaboration and facilitating the user letting go momentarily of "control" in the experience for their benefit.

STUDY LIMITATIONS

A limitation of our work is that additional insights may have emerged if participants had hosted Ava for longer. However, we believe that two weeks' study time can provide initial results useful for designers to start further investigations. Furthermore, we focused on existing eBike riders; further study with non-eBike riders might enrich our contributions, as they would likely experience Ava differently.

We recognize that further evaluation of the gyroscope in steeper conditions could have been done before offering Ava to participants. In prevention of events like this we had programmed Ava so that engaging with the brakes disables the assistance, and no participants were injured. A future version could benefit from being aware of the road inclination using map data to calibrate the gyroscope angle.

FUTURE WORK

This paper highlights the research potential that integrated exertion can offer to support the physically active human body. As follows, we propose future work in this area:

A redesign of Ava could focus on investigating social cycling and use tactics 1, 5, 6 from a *ludus* perspective for game making by adjusting the tactics in relation to the environment and the players interaction with one another.

Furthermore, exploring other systems that could integrate with the body during exertion will benefit from tactics 2, 3, 4, 7 as these focus on bridging the body of the user and the system during exertion.

Future studies will focus on adding information from the environment to the exertion system as discussed in tactic 7, to explore integrated exertion and momentarily reduced body control from a functional and playful perspective towards understanding the user experience.

CONCLUSION

Our work highlights the emerging area of integrated exertion, focusing on support *during* the exertion activity, in this case, through sensing and actuating to facilitate integrated exertion between the rider and the system. We presented research on Ava, the eBike, a system designed to support actuating during exertion; analyzing participants' experiences gave rise to four design themes and seven design tactics that extend our knowledge of how these systems can support the physically active human body, and how they can contribute to new user experiences. Establishing such groundwork now is important, as more systems are emerging that can be easily extended to integrated exertion (eg. [7, 55, 57, 64]).

Our work presents a timely understanding that serves as a foundation for the evolving field of integrated exertion. We invite designers and game designers who want to explore engaging in new ways with the physically active human body to use the presented themes and tactics. As a result, we hope that more integrated exertion experiences are created so that more people reap the benefits of engaging with the physically active human body.

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