Designing for the impossible: Creating a mobile application to track time travel

Daniel Buzzo
Creative Technologies Lab
University of the West of England
Coldharbour Lane, Bristol, UK
daniel.buzzo@uwe.ac.uk

David Jonas

The PatchingZone
Rotterdam, Netherlands
davidjonasdesign@gmail.com

In this paper we discuss the development of TimeTravel, a mobile application for tracking personal time dilation. Time dilation is the relativistic warping effect on time that velocity and gravity produces. Predicted by Einstein's Special theory of relativity (1905) and verified by practical experiment, (Hafele and Keating 1972) time dilation affects all things in motion, anywhere in the Universe (Reinhardt 2007). Our project was to develop a simple application aimed at smart watches that could communicate the imperceptible effects of time dilation on a user's everyday activities in an easy to understand, meaningful way. We describe the development and consider what happens when we attempt to visualise the imperceptible

Interaction design, time, temporality; visualisation; user experience, usability; making

1. INTRODUCTION

The interface and UX design processes contained challenges in our quest to communicate this highly abstract concept in an engagable, easy to understand way. We employed an iterative process, considering conceptual, functional and visual design. Alongside this we encountered technical challenges in tracking and calculating time scales in the trillionths of seconds or less (ten to the minus twenty or smaller durations) and of programming for an uncertain execution stack.

Figure 1: A caesium beam timepiece used in the U.S. space program occupies a first-class seat aboard a TWA flight from London to Washington on Nov. 23, 1966. This formed part of the famous Hafele-Keating experiment published in 1972.
Photo: Jackson, Getty Images.

Underpinning the design and technical challenges our developmental progress moved from wireframes and functional demos in high-level web technology based (HTML, CSS and Javascript) application development environments (Calvium's AppFurnace and the IntelXDK) to the decision to migrate to native Android development in AndroidStudio. At the end we consider the development of our project and discuss the ideas of representing information to an individual about themselves that would not ordinarily be detectable. Contrasting with many other visualisations, heat, light, speed, effort etc that an individual can ordinarily perceive we conclude that we are visualising the imperceptible.

We approached the exercise as a design led arts research project. Specifically situated in the arena of media art and critical design, as popularised by Dunne and Raby (2007) and discussed in detail by Shankin (2002). We also borrowed ideas from the exploratory design techniques of Gaver et al (1999) and Research Through Design as a means to gain insights on the core objective of the project.

Although the project is focussed on generating usable, commercially available software for mass consumption this is not it’s primary goal. Working in a making/arts/exploratory technology context we seek to ask the question as to how we live, temporally, and what the nature of the modes of personal data visualisation may be. This project seeks not to create a scientific tool or a teaching aid to explain a theory from the world of physics but to propose a question about how we perceive the world. Asking what may happen when we visualise seemingly impossible or contradictory things.

The research project is a continuation of previous research efforts (Buzzo 2014) combining practice led media art and theoretical research (Buzzo 2013) in the field of perception and representation of time. Our design is at pre-release stage and as an on-going project will iterate further in the run-up to wide-scale release and, we hope, in subsequent revisions. We wish to share our work so far to engage in a dialog to improve our next stage user testing processes.

Our project has developed a simple mobile application in an attempt to communicate an abstract concept to users of the application. This research through design approach is used to investigate and demystify an esoteric concept from theoretical physics with the aim of lay communication through practical example. At the same time as designing we were also investigating in an ethnographic way what awareness of time dilation may feel like.

Previous work in the field of physics such as Hsuing et al (1990) has investigated visualisation of time dilation, in a general sense, but this has primarily been for an expert audience rather than aimed at personal visualisation. There are several functional applications that operate as 'calculators', allowing users to enter velocity, duration etc and have dilation figures calculated for them. None of these actually make any attempt to link this to personal, lived experience nor make calculations based on live, sensed data. It is this point of the live and personal nature of the application and visualisations and calculation that is central to the project.

This projects builds on previous work investigating the personal micro-scale effects of relativity whilst attempting to communicate a macro-scale context.

Previous work visually documented extended periods of airflight and investigated the subsequent effects of time dilation at a personal level. In this project we change the focus to everyday effects and are deliberately targeting a wider user group with an interactive project.

PROJECT OUTLINE/ AIMS

Time dilation is described in Einstein's Theory of Relativity and is the difference between the elapsed time measured by two observers moving relative to each other. The fundamental aspect of the recording and visualisation of time dilation is the effect in relation to other things. How one's movement in space and time changes relative to a common base or a fixed point, considered an observer. Or in our case, other individuals, friends moving separately in time and space at differing speeds.

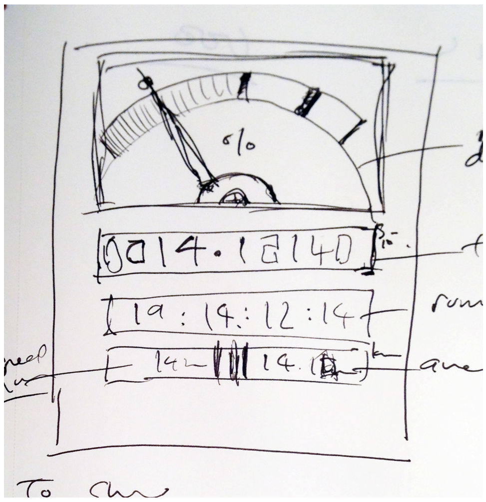


Figure 2: Original sketch ideas for physical equipment styled visualization showing instantaneous time dilation effect, elapsed time, and accumulated dilation.

In many of the popular science explanations of time dilation the example of two twins is often used. One departing on a rocket ship and the other remaining on earth. After a few years of space-flight the cosmonaut twin returns to earth to be reunited with his or her now elderly sibling. The velocity of the traveling twin having dilated time, as a function of traveling through space.

This illustration is on one hand easy to grasp but on the other still is rooted in a very abstract set of circumstances. Unless you have a twin sibling, and one or other of you possesses a functional interstellar vessel capable of achieving velocities close to the speed of light it is still in the realm of fantasy.

The first practical experiment demonstrating evidence of time dilation was the Hafele-Keating experiment of 1972. Simply put this involved flying highly accurate caesium atomic clocks around the globe and comparing the time they recorded with a previously synchronised stationary clock. (see figure. 1) The experiment showed the moving clocks experienced different amounts of time compared with the stationary one. The resulting time differences were in line with Einstein's predictions of the effects of time dilation. Subsequent experiments have illustrated the phenomenon in numerous different ways.

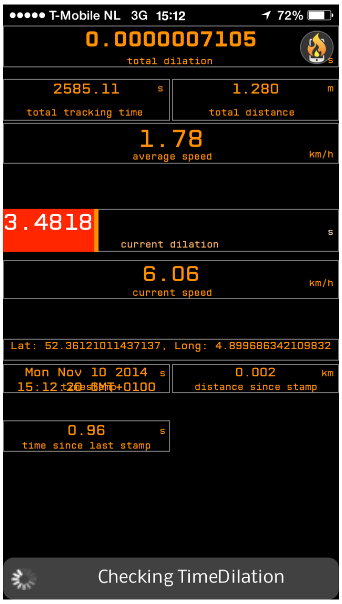


Figure 3: prototype iterations in Calvium's Appfurnace IDE showing extensive debugging data. Latitude, Longitude, velocity, time since last geo-location event, instantaneous dilation etc.

Time dilation is affected by both gravitational and velocity effects. For our approximation we make the decision to discard the gravitational effects of altitude and concentrate on dealing with the effects of velocity. Although we could anticipate some users engaging in air-travel when using the application without leaving the planet for orbit and beyond the effect of varying velocities is by far the larger.

Previous research projects on the time dilation aspects of airplane flight, 'Time travel: Time dilation' [2] sought a better way to communicate the individual nature of time travel. We hoped to continue the investigation of a lay understanding and conceptualisation of the personal applicability of time dilation. The quest to generate a key personal understanding of the actuality of the effects of time dilation on every individual led us to a design for mobile platforms.

Mobile computing devices, mobile, phone, tablet and particularly the new generation of 'smart watches' were considered the ideal platform on which to create a simple intervention to convey the core idea. The common incorporation of GPS for geo-locative purposes into these devices was central to the potential success of the design. Ironically the calculations involved in the working of the GPS, Global Positioning System, incorporate calculations for time dilation due to velocity and gravitational effects, in part informed by the experimental work of Hafele and Keating.

PROJECT DEVELOPMENT

Our core design proposition was straightforward, to track the velocity and timing of an individual via geo-location techniques on a mobile platform. Then use the geo-data to calculate time and velocity and display any subsequent dilation effects relative to a (theoretical) fixed basepoint.

The possibility of encouraging users to compare their own dilation with others was seen as an important additional feature. We hoped this would be a step toward reinforcing the realisation of the actuality and intrinsically personal nature of time dilation that the project sought. Sharing details of the amounts of accumulated time dilation by users and articulation and comparison of the reality of time dilation and comparison being key to this concept.

Our research and development process went through several simple steps;

- initial conception, discussion, translating the physics into math and then code;
- concept and interface iterations;
- prototype iterations across platforms;
- analysing and solving timing and performance issues;
- discussion of design for AndroidWear;
- discussion of success criteria and specification;
- collaborative iterative working.

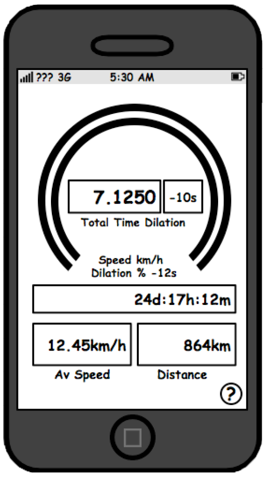
INTERACTION DESIGN

Starting from basic functional investigations, discussion (see figure 2) and visualisations the project generated key requirements. Through iterations of the requirements and visualisations a first version minimum viable product (MVP) was arrived at, comprising;

- Geo-Locative Tracking;
- Calculation of instantaneous dilation effect;
- Readout of total dilation (since reset; similar in design to an automobile trip meter);
- Readout of average speed (as above).

Secondary functionality that was felt to be desirable included

- Tools to share total and/or weekly dilation in with other users;
- A high score style table to create the ability to compare totals with friends.



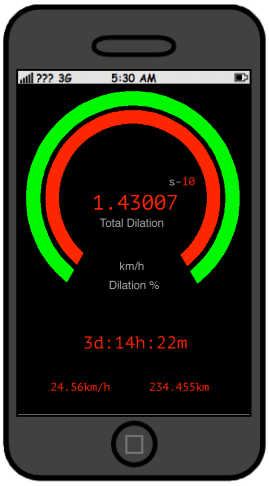


Figure 4: Iterated sketch designs for interface showing speed and instantaneous dilation readouts and curved/circular displays.

Figure 5: Early high-resolution wireframe interface example including elapsed tracking time and elapsed dilation factor – compared to theoretical fixed basepoint

Software and platform development

The software platforms considered were Android and iOS, Android being chosen as the initial development platform for reasons of programming, testing and deployment convenience. The Android OS running on a watch styled device was targeted as an ideal candidate hardware platform. This was felt to be effective both from a form and interaction factor but also given the intimate link to ideas of time that a watch styled device evokes. From a mathematical and software point of view the base calculation for time dilation is relatively straightforward –

The effect of time dilation is non-linear in nature. At low speeds the effect is extremely small. However, as the velocity, v, approaches the speed of light c, (3×10^8m/s), the dilation effect increases dramatically from $t^1/t = 1 (v = 0)$ toward $t^1/t =$ infinity at v = c, where in theory, time ceases to have relevance.

Figure 6 Illustrates the calculation for time passed at origin, considered to be a static observer, compared with the time that passes for the object in motion.

$$t' = \frac{t}{\sqrt{1 - \frac{v^2}{c^2}}}$$

Figure 6: Calculation of time dilation compared to a fixed observer

Due to generally low speeds we were anticipating to measure extremely small intervals of time would need to be considered from the outset. The accuracy of the target equipment and the measuring process we decided to employ necessitated a very high degree of approximation within the measurements and subsequent calculations. As a result it must be emphasised that the visualisations we are seeking to create for users are indicative but highly generalized. We are only attempting to account for the effects of velocity on time dilation and not that of gravity.

As expected, early iterations of the code to calculate dilation were found to be returning extremely small quantities. The relative dilation we were observing being in the region of 10^{-15} to 10^{-20} and so small that there were initially problems returning results that were not truncated as zero by the precision depth of the languages used. The range of dilation related to motion, from static to walking speed to modern air transportation gives an issue with our chosen style of linear readout. By manipulating the readout results by varying logarithmic scaling factors we were able to consistently generate usable results from our original core time dilation calculation functions.

We analysed the efficiency of timing functions in the target software platform. Unfortunately it quickly became apparent that the variability of processing time and system lags could introduce significant errors in the calculations and processing stack. Given that we are investigating extremely small durations requiring high levels of accuracy this was revealed to be a significant problem.

After much consideration it was decided to opt for an alternative strategy that would regularly sample the velocity of the host mobile device and from this data build a 'best guess' approximation of the actual time dilation. As GPS usage increases power consumption on mobile devices the velocity sample rate can be increased and decreased from seconds to minutes to increase accuracy or preserve battery life. Incidentally it is worth noting that the geolocation API system samples data at rate determined by the host device. In our case a relatively slow rate (>0.5s per sample). Additionally GPS has a generally acknowledged accuracy of between 7.8m (with a confidence of 95%) up to 3.5m for high quality GPS SPS receivers (www.gps.gov). These two factors combined mean that small body movements, such as the swinging of a users arm, have no influence on the accuracy of our measurements.

Whilst the approach of back calculation based upon velocity is significantly less accurate and less desirable than a mathematically more accurate approach it was felt to be an acceptable compromise to achieve the end goal. That of making a first-order intuitive system, that uses an approximate idealization, Since we are using GPS speed measurement, our reference frame is the 0 m/s gps reading, meaning a stationary point relative to the latitude and longitude coordinates on earth's surface.. A system that reinforces awareness of the personal nature of dilation rather than being an accurate scientific tool.

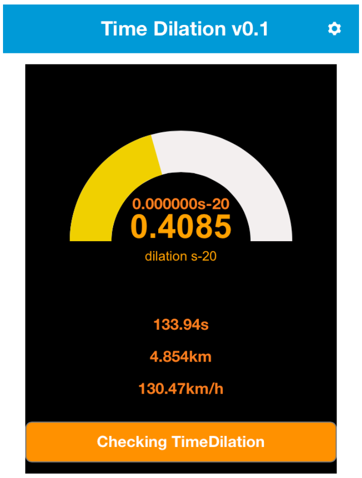


Figure 7: Screenshot from prototype developed in intelXDK IDE showing use of dial graphing libraries and immediate dilation feedback.

Design iterations

The visual interface went through several iterations and the core functions were refined at each iteration. The prototyping progressed across three different frameworks, Starting with web based technologies in the Appfurnace rapid prototyping tool from Calvium (see figure 3) then progressing to the IntelXDK development environment. (see figure. 7)

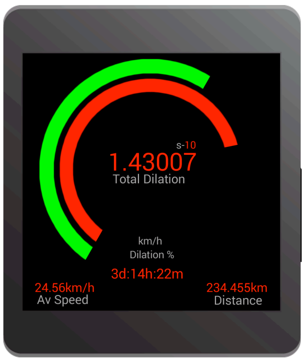


Figure 8: Early prototype design for AndroidWear form showing current dilation and velocity as arc readouts, accumulated dilation, average speed and distance travelled (since last reset)

The particular advantages of beginning work in the Calvium environment is the speed with which simple interfaces can be assembled with the capability to easily incorporate custom code routines, In this instance in JavaScript. The speed with which a simple prototype of the sketched code routines and simple interface can be generated is mirrored by the speed of deployment of prototypes to Android and iOS mobile devices. Using cloud based repositories for the prototype designs allows 'through the air' deployment into test player applications on various mobile devices.

Following initial designs of interfaces we sketched out descriptions of code routines that would be needed to calculate the core functions. From this base a working prototype was produced extremely quickly. Iterations to the interface and code calculations were similarly deployed over the air making testing and development an efficient process. Initial testing was based on self observation of traveling with devices, iOS and Android, running early versions of software. Improvements to code routines and information presentation came from early ethnographic testing. Modifications to interface elements and interaction behaviour came from informal testing and interviews with a variety of technology literate early users.

After some iterations a custom JS (JavaScript) library of core time dilation calculation functions was created. This allowed a test-bed using a variety of calculations from percentages of light speed to observer's time to be performed.

Figure 9: Prototype revisions for Android watch interface illustrating current velocity and dilation factor compared with theoretical fixed observer.

Subsequent to successful testing and verifiable results the project moved to the AndroidStudio IDE and was re-coded in Java. AndroidStudio, whilst having a larger development overhead allowed development of applications with access to more native platform resources, principally the ability to continue to execute on the target device when the application was running in the background. Both AppFurnace and IntelXDK have clear routes to commercially deployable applications but their current lack of AndroidWear players and the advantages of native coding were the main factors in the decision to move to AndroidStudio.

Having proved the code functions, architecture and interface in the initial prototypes re-coding in Java in the AndroidStudio IDE was a relatively straightforward process. Initial testing was on Android smart phones using a variety of travel methods, walking, cycling, tram, car and train. This gave a variety of real world velocities to test calculations against.

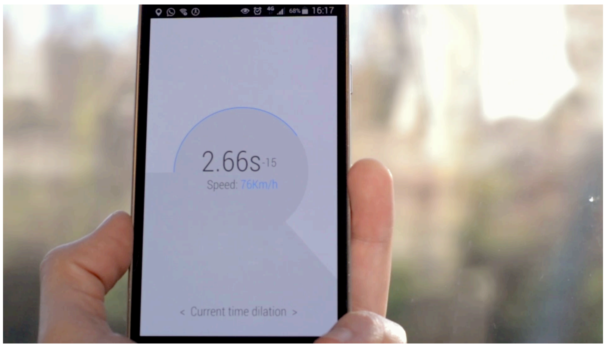


Figure 10: Prototype testing on Android based phone showing actual dilation calculated whilst travelling at speed on an intercity train.

After obtaining a number of AndroidWear smart watches, Sony SmartWatch 3 model SWR50 (See figure 11) we were able to do initial deployment into the smart watch format. Certain elements of the application packaging at compilation time are different within the AndroidStudio IDE. These are mostly associated with the deployment context, usually via a tethered Android phone where our application would be unpacked and the AndroidWear context subsequently loaded to the smart watch via Near Field Communication (NFC) tethering or Bluetooth.

Deployment and testing

Initial deployment of early prototypes was immediately helpful in providing feedback and field testing to the iterative design process. Early iterations of the design displayed greater amounts of information relating to the geo-locative tracking process, displaying latitude, longitude, elapsed time between geo-tracking updates etc. (see figure 3) It quickly became apparent that much of this information, whilst interesting from a development and debugging perspective, was irrelevant and unnecessary to convert the key message of the project.

An awareness of the personal nature of the relativity of time.

The design and presentation of information on screen was reconsidered in constant review with a series of early user consultations. Initial feedback indicated the designs presented a scientific instrument, (see figure. 4) that once explained to users had initial novel interest but lacked the personal connection the project aimed to evoke. Subsequent designs adopted metaphors from real-time physical displays in the style of a classic VU meter combined with an approximation of an automotive speedometer (see figure 5).

Figure 11: Sony SmartWatch 3 model SWR50 chosen for testing contains in-built GPS capability which allows our application to work without the necessity of a tethered Android phone.

The adoption of a moving indicator giving real-time visual feedback rather than just textual feedback of the instantaneous subjective time dilation yielded particularly positive feedback. It appears that users were able to connect the imperceptible changes in their subjective experience of time directly to their speed of motion, walking or traveling by train etc. After moving from prototypes deployed in small numbers to the target development platform, AndroidOS, A wider circle of testers were used in advance of deployment to the Android application store for release version 1.0 (see figure 8)

Further refinements adopted new Android UI guidelines more closely, making a more seamless integration into the overall wearables context. Anticipating the personal and physical nature of what we wanted to convey we also incorporated visual references from the styling of quantified self and health and fitness tracking software. (see figure 9)

FEEDBACK FROM USERS

Early feedback from alpha test users is positive, with subjects reporting emotional responses to the information communicated from the application. Several users indicated a 'sense of wonder' with a small number conveying a 'sense of disorientation' when considering the challenge that the concept of personal time dilation brings. This response was considered a particular success.

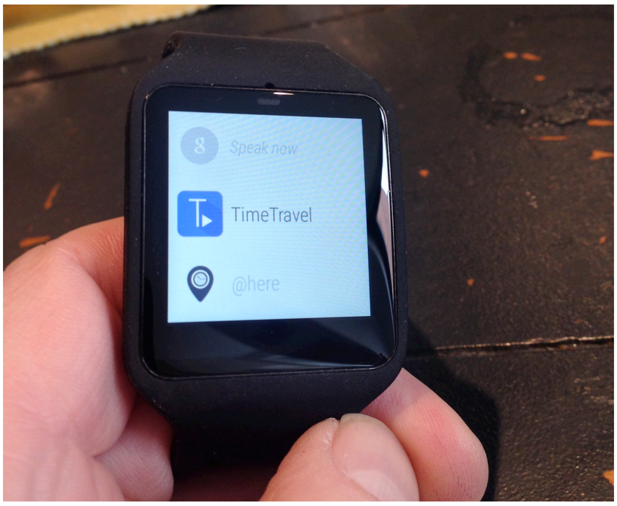


Figure 12: Prototype testing of our application on Sony SW3 SWR50 AndroidWear smart watch.

FURTHER DISCUSSION

So far the project is at the end of the first stage and though we have viable working prototypes it is anticipated that there will be several more cycles of work. We are attempting to visualise something usually considered abstract and intangible. Our next goal is to engage a wider discussion and greater user numbers to allow statistically significant research to be undertaken on how the application affects the perceptions of users.

Our next stage is to conduct an adoptive user study (n =< 10) with a small number of users with Android smart watches devices. In the adoptive strategy we ask users to engage with the application for an extended period of time. We are primarily interested in studying what if any changes occur when we present seemingly impossible concepts such as the speed of light and the warping of time in visual form to users. Following this adoptive process we will engage in user interviews and evaluate the findings with a view to both further design iterations and reporting of research findings.

At this point in our research we wish to engage in a wider discussion as to the best process to evaluate the next stage of our project. We are working in the arena of making the invisible immediate. The arena where we are augmenting our senses through technology - such as experiments in making wi-fi signals perceivable (Arnall and Knutsen 2011) or detecting magnetism (Nagel et al 2005) - changes the context of how we live and how we may comprehend our world.

We see our project as a bridge between the lived and theoretical worlds and present it as a practical investigation into what happens when we make the imperceptible perceivable.

ACKNOWLEDGEMENTS

We wish to thank Dr. Graham Meaden at the University of Bristol School of Physics for assistance with mathematical interpretation and Emily Buzzo for graphic design guidance.

REFERENCES

Buzzo, D. (2013) Lost time never. In: Input Outputs conference proceedings.

Buzzo, D (2014) Time travel: Time dilation. In: Electronic Visualisation and the Arts, 170–176.

Buzzo, D (2014) TIME TRAVEL:Time dilation and a year of airflight - recent photographic work. Forlaegger Fabrik20/Blurb.

Dunne, A., and Raby, F (2007) Critical design faq, [Online; accessed 20-November-2014].

Gaver, W., Dunne, A., and Pacenti, E (1999). Design: Cultural probes. Interactions 6, 1.

Hafele, J. C., and Keating, R. E (1972). Around-the-World Atomic Clocks: Predicted Relativistic Time Gains. Science 177, 166–168.

Hsuing P.K., R. H., Thibadeau, R. H., Cox, C. B., and Dunn, R. H. P (1990) Time dilation visualization in relativity.

Nagel, S. K., Carl, C., Kringe, T., Martin, R., and Knig, P (2005) Beyond sensory substitution: learning the sixth sense. Journal of Neural Engineering 2, 4, R13.

Reinhardt, S. e. a (2007) Test of relativistic time dilation with fast optical atomic clocks at different velocities. Nature Physics 3, 12, 861864.

Shanken, E. a. (2002). Art in the Information Age: Technology and Conceptual Art. *Leonardo*, *35*(4), 433–438.

Timo Arnall, Jrn Knutsen, E. S. M (2011) Immaterials: Light painting wifi. [Online: Accessed 10th December 2014].