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NanoCar Educational Project, Game

Bachelor's Project Computing Science

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Abstract

The nanocar is a molecule that is capable of moving when stimulated by UV light and heat. It is a tremendously small car, only three nanometres in length, and consists of 194 atoms. It is a great breakthrough technology that can allow the creation of many beneficial things, such as smart drugs or the manufacture of computer circuitry. Social awareness of this invention, however, is very narrow, and not many resources exist to explain this concept. For this purpose, we created an application containing an interactive presentation and a game. To evaluate the impact of our application, a user study was conducted focused on the knowledge of the participants on the subject before and after they used our application. The results seem promising; some components can be improved, and the contribution between the game and presentation was not equal.

Contents

1 Introduction

When asking a random person about the nanocar, the most likely response you would get is, What car? Some would vaguely remember that the project won the Nobel Prize of Science in 2016 [1], but still would not know what it actually is. Our application intends to change that. We are creating a game and a presentation to explain the nanocar to the general public. This work will mostly evaluate the progress for the game part and, where needed, discuss the presentation part.

1.1 Nanocar

To better understand what the project is about, this section contains a small interlude to explain what a nanocar is and how it works. The nanocar is a really tiny element made up of a small number of atoms; the one shown in our applications consists of just 194 atoms; see Figure 1. The atoms of the car are carbon, nitrogen, and hydrogen. The nanocar name

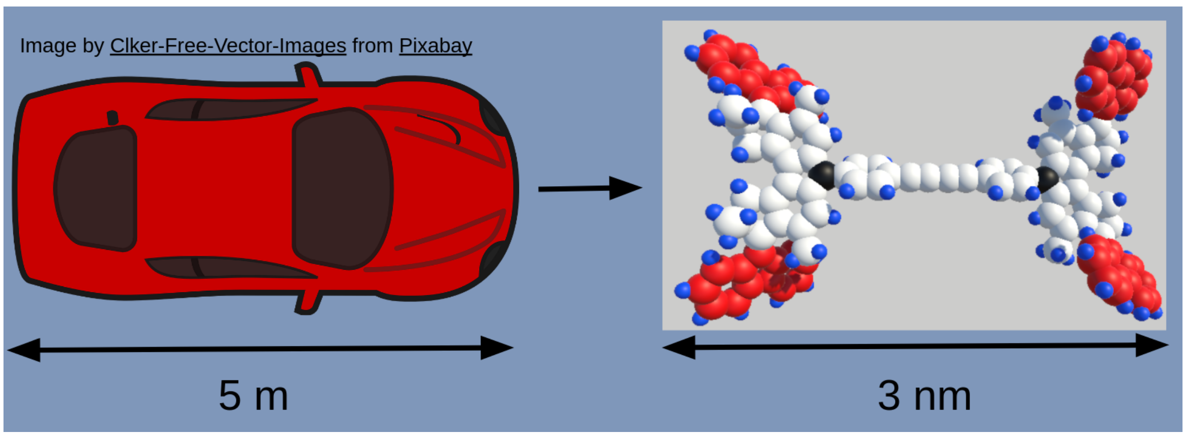

Figure 1: Left: a normal car of roughly five metres; right: a nanocar of roughly three nanometres.

comes from its size; the nanocar is roughly three nanometres. Like a conventional car, the nanocar is able to drive over a surface. However, instead of the usual rough asphalt road, the nanocar drives over a surface of atoms. Everything the nanocar does is on a nanoscale; think of engine, wheels and speed. The wheels are where the nanocar differs from a car in our macro world. Each wheel has its own engine, and the car does not yet have a means to bring its own fuel. Therefore, the car is powered with either a laser (photons) [2] or a Scanning Tunnelling Microscope (electricity) [3]. This power source excites the engine in the car, which moves the wheels one half or a full rotation; see Figure 2. The remaining heat is used to lock the wheels in their new orientation. If too much energy is given to the car, by, for example, bombarding it with too many photons, the car is unable to shed all the heat, becomes overexcited, and will explode. The current iterations of the car are driven in an interference protected environment and vacuum. Currently there are no real-world implementations for the nanocar; however, the hope is nanocars could become useful in creating smart drugs or the manufacture of computer circuitry in the near future.

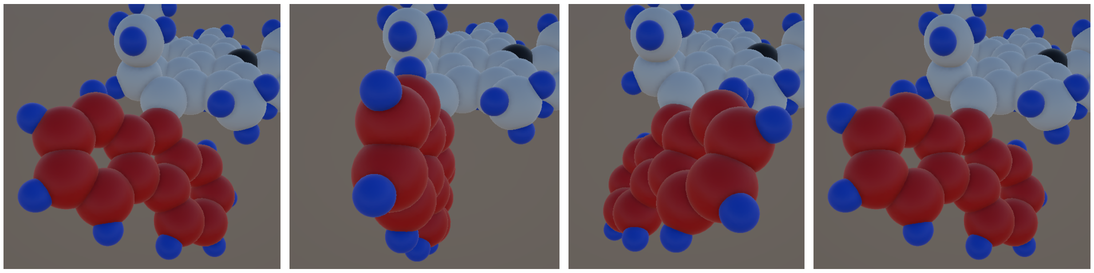

Figure 2: From left to right: the rotation of the wheel.

1.2 Goals

As mentioned before, the goal of the project is to create an application to explain and visualise the nanocar for the general public. The application is intended to be presented at the Osaka World Expo in 2025 [4], at the university itself and potentially other smaller symposiums. The application needs to be fun, informative, easy to use, everything done by touch screen, foolproof, automated when there is no user input and would only take a couple of minutes to go through. Furthermore, the application should preferably run on a simple Windows PC. To reach these goals, it was decided to split the application into two parts, a game and a presentation. To evaluate the effectiveness of our application, the following research questions were constructed:

1. What is the impact of the nanocar game on the knowledge of people about the nanocar?
2. What is the impact of the interactive presentation on the knowledge of people about the nanocar?
3. How user friendly are the game and presentation according to the subjective rating of the users?

Since the focus of this work is mainly on the game part of the application, only question one and part of question three are handled here. To read more about the presentation, see the companion report by S. kucharski.

The next chapter will briefly discuss related works. Chapter 3 will go over the model and implementation. In Chapter 4, the user study and its results will be evaluated. The conclusion and future works will be given in Chapter 5, 6, respectively.

2 Related Works

The goal of this project is to explain what a nanocar is to the general public; therefore, it is closely related to research on the nanocar. The model and behaviour of the car are designed to closely resemble what is explained by Kudernac et al. [3]. The activation of the wheels, stimulation of the engines, resembles the concept mentioned by Koumura et al. [2]. Furthermore, the game is set up as a race. The goal is to race, as fast as possible, on a surface of atoms, in a straight line, to the finish line. The racetrack, race environment, and time aspect are based on the nanocar competition [5], [6]. Unlike the game, which is set up to add a fun component to the project, the competition is set up to push research on nanocars forward.

On the informative side, there is not much related work regarding this project. There exists some informational work [7], [8]. However, these simply contain images of the nanocar; none contain any interactive components. The second informational source [8] does have an image suggesting some similar application exists. Sadly, no trace of this application can be found. Most likely the shown scene was purely generated for the image, or the tool is only internally used.

3 Model & Implementation

This section will briefly discuss the model and then will go over the implementation.

3.1 Model

The interactive game should allow the user to assemble and drive the nanocar on a surface generated using Brownian motion. The goal of the game is to inform the user how the nanocar works, behaves, and the challenges it encounters at the nanoscale. The user can touch the car to simulate a photon beam energising the car to move it around. Each pair of wheels, front and back can be influenced separately, and the car can explode when overloaded. The goal for the user is to reach the finish in the shortest time possible. The game in its current state is shown in Figure 3. The goal is highlighted with the orange orb shown in the left image. On the left side of the game screen, an indicator shows how close the car is to overheating (exploding).

3.2 Implementation

For this project it was decided to use the Unity game engine [9]. A game engine offers a set of tools that makes it easy to create user interactions or a user interface and handles most of the low-level visualisation. If needed, it is still highly modifiable but offers a nice basis for a project like this. The Unity game engine was chosen because most of the team had prior experience with Unity, there is a lot of documentation online, Unity is multiplatform, and it is one of the smaller game engines. The multiplatform ability offers flexibility for whenever a web build or a build for another operating system is needed. The compact size of the game engine means the developers are less limited by their own system. The main language used for Unity is C#, meaning most, if not all, of the code will be written in C#. 3D models are going to be created using Blender and Fusion 360. The codebase will be stored and maintained on a

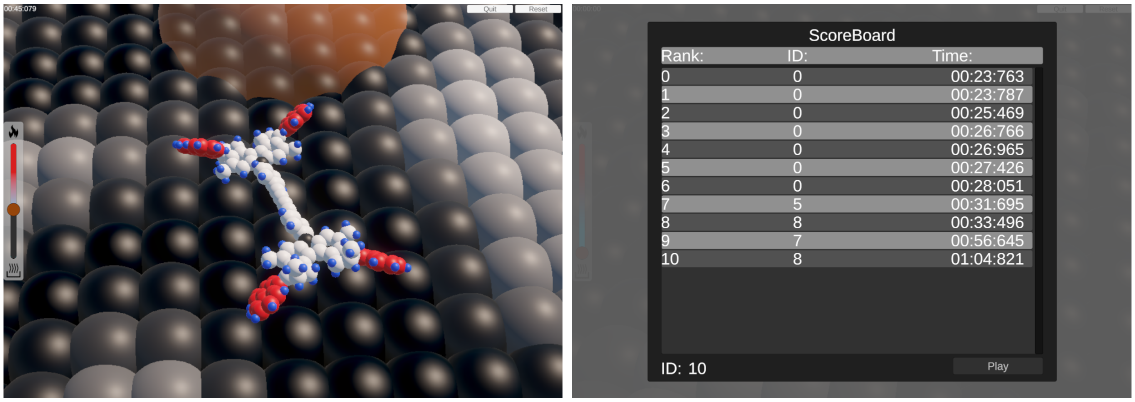

Figure 3: The game. Left: the game itself; right: the start screen with the scoreboard.

currently private repository on GitHub [10]. The landing page for the user study and version of the game used for it are hosted on GitHub Pages [11].

In the current version of the game there are three main components: the UI, the car and the floor. The UI is simply created with some Unity scripts and Unity tools. The main screen for the game is the scoreboard shown on the right in Figure 3. When on the scoreboard screen, the game is greyed out but still running; however, the user can only interact with the scoreboard; other inputs are blocked. On the bottom left of the scoreboard, the player can see their ID; on the bottom right, they can start playing the game, and in the middle, the scores are shown. The scoreboard is not saved between launches; this should be fine since the game is meant to be run for long durations. The user ID is a simple number and is updated after every race. Having the user ID as a number adds simplicity to the game, removes unneeded user interactions, and removes the need for complex language checks. To make it easier for the user, their race time is connected to the ID that is visible after they finish the race.

After the user clicks on play, the scoreboard closes, the grey blocker is removed, and the game becomes visible, as shown in Figure 3. The user can move the car by pressing on it, either with a cursor or with touch. When pressed on the body, all four wheels will move; when pressed on the front or back wheels, the front or back wheels move, respectively. After the first press, the timer in the top left corner will start, and the race has begun. When the nanocar touches the finish, shown on the right in Figure 4, the race will end and the scoreboard will be opened. During the race the user can make use of the two buttons in the top right of the screen. The Quit button will end the race and increase the user ID. This button allows the user to stop the game if they get bored or allows a new player to go back to the scoreboard if someone left the game timer running. The Reset button puts the user back in the start position and resets the timer. The user can use this button if they get stuck or if the run takes too long for a good score. The final mechanism of the game is heat, depicted by a heat bar on the left of the game screen. A close-up version of the heat bar and its various states is shown on the left in Figure 4. When nothing has happened for a while, the heat bar is in the state shown in the leftmost image. Whenever the user presses on the car, a bit of heat is added to the bar as shown in the middle image. When there is no input from the user, the heat slowly dissipates. If at any point the heat reaches the top of the bar, as shown in the third image, the nanocar explodes, which in the current version of the game is shown by simply resetting the car back to the start position.

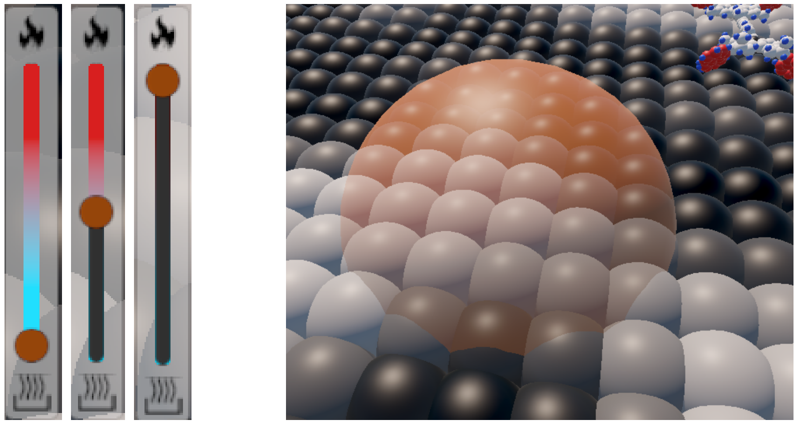

Figure 4: Game components. Left: the heat indicator in three states: empty, half, and full; right: the finish sphere.

The car and the floor are constructed from Unity game objects. Each sphere in the car and floor is its own spherical game object with its own spherical collider. For the car, the wheels are separated into their own group to allow them to rotate. The development side also contains a script to easily update the car whenever there is a change in the model. The floor was made from individual spheres to allow it to be dynamic. Each individual sphere moves up and down to give the floor a wavy appearance. To better visualise this behaviour, the floor changes colour from white (highest position) to black (lowest position). However, having the floor consist of all individual spheres raises an issue. For a complete level, the floor could be quite big, meaning a lot of game objects are needed. Too many game objects, and it will impact the performance of the game. Therefore, a system was designed to limit how many floor spheres exist in the scene. The floor spheres are rendered in a fixed circle around the car. Whenever the car moves, the floor is updated as shown in Figure 5. Each sphere that falls outside of the new circle is updated in this way.

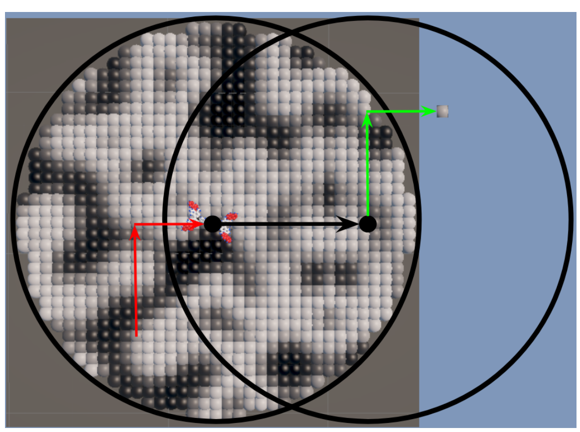

Figure 5: The way the floor under the car is generated. The location of a floor sphere is compared to the old position of the car (red arrows) and then placed according to the new position of the car (green arrows).

4 Evaluation and Results

To determine the usefulness of the game and the presentation, a user study was conducted. The participants of the user study were gathered among students from our university, family and friends. Some participants had prior knowledge of the nanocar, but most did not. In total, the user study was filled in by 42 participants, some in person, others via an online stepwise instruction page [11]. The user study was split into three phases. In the first phase the participants had to fill in a small questionnaire testing their knowledge of the nanocar. In the second phase the participants were allowed to play around with the game and presentation. Since the game and presentation lack guidance, the participants were given some simple instructions on how to play the game and go through the presentation; this was either mentioned to them or written out on the instruction page. In the final phase the participants were again tested on their knowledge of the nanocar and had to fill in a small questionnaire about their experience using both applications. The results of both questionnaires are discussed below.

4.1 Knowledge before and after

In both questionnaires the knowledge of the participants of the nanocar was tested. In this section the results of their knowledge before and after using our applications are compared (called before and after testing from this point). The correct answers are also marked.

What are the elements that the nanocar is made of?

Element	Before	After	Correct
Hydrogen	45.2%	73.8%	✓
Nitrogen	31.0%	76.2%	✓
Carbon	76.2%	85.7%	✓
Sulfur	14.3%	4.8%	-
Helium	11.9%	9.5%	-
Lithium	28.6%	7.1%	-

Table 1: Results before and after: What are the elements that the nanocar is made of?

For the first question in Table 1, hydrogen, nitrogen and carbon are the correct answers. Carbon clearly sticks out both before and after testing. Still, after testing, carbon is selected 10% more. Before testing, hydrogen and nitrogen are also selected more often than the other elements; however, not as much as carbon. After testing, they are selected roughly 40% more, getting much closer to the carbon selection percentage. The values for the other elements decrease after testing.

What is used to move the wheels?

Source	Before	After	Correct
UV Light	33.3%	83.3%	✓
X-rays	9.5%	0.0%	-
Heat	26.2%	71.4%	✓
Vibrations	38.1%	9.5%	-
Soy sauce	9.5%	0.0%	-

Table 2: Results before and after: What is used to move the wheels?

For the second question in Table 2 UV light and heat are the correct answers. Before testing, in contrast with the previous question, there is no single answer that is selected much more than the others. The top selections before testing are split between vibrations, UV light and heat, where the wrong answer, vibrations, is the most selected answer. After testing, this mistake is fixed by most participants with the selection of heat and UV light rising above 70% and vibrations going down to under 10%. The other two answers, which already had a low selection percentage before testing, go to zero after testing.

What happens when you overexcite a bond?

Happening	Before	After	Correct
The car explodes	40.5%	76.2%	✓
Nothing	9.5%	4.8%	-
The car stops working temporarily but repairs itself after a while	50.0%	19.0%	-

Table 3: What happens when you overexcite a bond?

For the third question in Table 3 The car explodes is the correct answer. Before testing, most of the answers are split between the car explodes and the car stops temporarily, after which it repairs itself. After testing, some participants still selected the wrong answer of the car repairing itself, but most selected the right answer of the car exploding. The percentage of participants selecting that the car does nothing also went down after testing.

Can the car move forward and/or backward?

Direction	Before	After	Correct
Forward	45.2%	95.2%	✓
Backward	0.0%	0.0%	-
Both	54.8%	4.8%	-

Table 4: Results before and after: Can the car move forward and/or backward?

For the fourth question in Table 4, forward is the correct answer. Again, before testing, most of the answers are split between 2, forward and both. After testing, almost all participants correctly selected that the car can only move forward. However, some still thought that the car could also move backwards. Before testing, none of the participants assumed that the car could only drive backwards; this did not change after testing.

How big is the nanocar?

Size	Before	After	Correct
$3mm$	9.5%	7.1%	-
$3\mu m$	16.7%	11.9%	-
$3nm$	71.8%	81.0%	✓

Table 5: Results before and after: How big is the nanocar?

For the fifth question in Table 5 $3nm$ is the correct answer. Most of the participants selected this answer before testing. After testing even more participants selected this answer. However, almost 20% still selected one of the other sizes.

There is a clear trend visible in all the knowledge questions. The selection percentage of the correct answers is much higher after testing than before. This shows that our applications are able to convey information about the nanocar to the participants. In some questions, some of the wrong answers are reduced to 0.0% Table 2. While in others there is still a significant percentage of the participants that chooses the wrong answer as seen in Tables 3, 5. The significant percentage of wrong answers could be explained by the state of the applications. Currently the applications are not completely finished. The only thing in the presentation indicating the scale of the car is a scale in the bottom right which could be overlooked by the participants. The explosion of the car is only briefly mentioned in the presentation. In the game the explosion is not yet implemented; the player is simply reset when overheating. Implementing the explosion and adding clearer indicators of the size might decrease the percentage of wrong selected answers on these 2 subjects.

4.2 What aspect of the application taught them what

After the knowledge questions, the questionnaire asked the participants to select which subject they learnt from the game and which they learnt from the presentation. In this section the results of these two questions are evaluated and compared.

What did you learn from the game or presentation?

Question	Game	Presentation
What are the elements that the nanocar is made of?	18.9%	87.5%
What is used to move the wheels?	48.6%	85.0%
What happens when you overexcite a bond?	70.3%	42.5%
Can the car move forward and/or backward?	81.1%	50.0%
How big is the nanocar?	27.0%	72.5%

Table 6: Results of: What did you learn from the game or presentation?

Table 6 shows the result. For the presentation all subjects were selected by more than 40% of the participants. For the game this is only true for three subjects, meaning overall the participants learnt more from the presentation than from the game. Looking at the numbers more specifically, one notices a distinction between the game and presentation. Where the presentation scores high in the first two and last subject, the game scores high in the third and fourth subject. The questions the game scores high in are about what happens to the car when overexcited and which direction it can move. Although these topics are mentioned in the presentation, the participants will see them firsthand in the game, which could explain why these topics score better for the game. The opposite can be said for the other three subjects. Since they are much harder to see in the game, there are no labels in the game to show elements and size; the presentation does a much better job conveying that information.

4.3 User satisfaction

At the end of the second part of the questionnaire, the participants were asked to evaluate their experience and the applications, and here they could also give general feedback.

Did you think you learned something?

Answer	Percentage
Yes	92.9%
No	7.1%

Table 7: Results of: Did you think you learned something?

In the first question in Table 7, the participants were simply asked if they felt like they learnt something. Most of the participants said they did.

How useful do you thing the game and presentation are for visitors?

Answer	Game	Presentation
very useful	21.4%	40.5%
useful	35.7%	42.9%
neutral	19.0%	11.9%
not useful	21.4%	0.0%
not at all useful	2.4%	4.8%

Table 8: Results of: How useful do you thing the game and presentation are for visitors?

The second and third question are combined in Table 8. In these questions the participants could rate the usefulness of the application for potential visitors at symposiums or other places where the applications are shown. The rating is from 'very useful' (5) to 'not at all useful' (1). The participants are divided on how useful they think the game is. There is a peak at both 'useful' and 'not useful'. The average of the responses sits somewhere in between 'useful' and 'neutral'. For the presentation there is a clear consensus between the participants. Most of the participants deemed the presentation 'useful', and an almost similar amount deemed the presentation 'very useful'. The average of the responses is probably closer to 'useful' but sits somewhere in between 'very useful' and 'useful'.

How much did you enjoy the experience?

Answer	Percentage
very much	38.1%
a bit	45.2%
okay	14.3%
not that good	0.0%
bad	2.4%

Table 9: Results of: How much did you enjoy the experience?

In the fourth question in Table 9, the participants could rate their experience from 'bad' (1) to 'very much' (5). More than 75% of the participants enjoyed the application 'a bit' or even 'very much'. There are also some participants that had a 'bad' time using our applications.

How would you rate the look and feel of the game and presentation?

Answer	Game	Presentation
nice	23.8%	26.2%
decent	28.6%	50.0%
standard	38.1%	21.4%
substandard	7.1%	0.0%
bad	2.4%	2.4%

Table 10: Results of: How would you rate the look and feel of the game and presentation?

The fifth and sixth question are again combined in Table 10. In these questions the participants could rate the look and feel of both applications. The scoring is from bad (1) to nice (5). The look of the game and presentation are generally deemed decent. A majority of the participants rated both applications as 'standard' or above. Again, the presentation performs better than the game. Where the game scores a bit shy of 'decent', the presentation is scored slightly towards 'nice'.

It is clear from the results that the participants somewhat enjoyed the experience and generally felt like they learnt something from the applications. Looking at the results of Table 8, 10, although the game does not score badly, the participants rated the presentation higher than the game. These are good results but do indicate that especially the game needs to be improved before it can be shown in a public setting. The general feedback of the participants follows a similar trend. A lot of the feedback states that both applications lack instructions and that the game could be better in showing when the nanocar explodes and how its wheels are energised. The feedback also showed an unrelated issue: people generally do not read. The game and presentation are unfinished and therefore lack an important feature, instructions. To amend this, an instruction page explaining how to fill in the user study, how the applications worked and some quirks of both applications was added to the user study. Sadly, a lot of feedback directly mentioned participants missing features or not understanding what to do due to these quirks. A lesson from this could be to try and keep the applications visual and remove as much text as possible.

5 Conclusion

From the result and the general feedback, it shows that, although not perfect, the game had a positive effect on the participants, was generally well received and was deemed suitable to show to visitors in a public setting. In comparison with the presentation, the game has slightly worse results on all fronts. Both the game and the presentation are on the right track but still need further development to achieve their full potential.

6 Future work

Both applications are further developed to ideally be finished before the Osaka World Expo in 2025. To determine if the team stays on the right track, there could be a similar user study later on in the project. This new user study could then be compared to the older one as well.

To better determine the usefulness of the applications, another user study could be conducted on the old participants one or 2 months after the one from this work. The user study would again test the knowledge of the participants on the nanocar subject. The results would show if the participants retained any of the information taught by the application. This could give interesting insights and might help with design decisions for the applications.

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