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**Abstract:**
The purpose of the study is to provide a FX TD, or others working with the art direction of fluid animation, with a better understanding on how the use of body forces, influences the perceived realism. The study also examines how the art direction is perceived and if the intended message is understood by the viewer.
The hypotheses were, that art directing fluid animation, by applying body forces, will lessen the level of perceived realism, but that it can be useful in communicating a desired feeling and message to the viewer. To investigate these hypotheses, three animations were created, that varies in the amount of art direction and body forces applied

These animations were shown to the participants in a user study, consisting of 56 women and 58 men, between the age of 16 and 61 years. After seeing each animation, the participants were asked a number of questions, regarding the perceived realism and the message of the art direction.

The results showed, that an increase in body forces applied, will indeed result in a significantly lower level of perceived realism. Whether an animation will successfully convey the feeling and message, intended by the FX TD, is difficult to determine conclusively, but the results of this study show, that it is possible to do so.
This paper has provided a vocabulary and tools that will help anyone working with the art direction of fluid animations and help them achieve the desired results.

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# PERCEIVED REALISM IN ART DIRECTED FLUID ANIMATION

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**APPENDIX**

# 1. INTRODUCTION

Special effects have been used in film since its inception, with pioneers like Georges Méliès using it to tell fantastical stories (Cook 2004). Along with the advancements in computer-generated images (CGI), the practical special effects have in many cases been replaced with computer made visual effects (VFX). Among these visual effects are physically based fluid animation, which is used to create realistic imagery of natural phenomena like water, fire and smoke.
The modern effects applications that are used to create these visuals are based on real-life physics and are as such able to create quite realistic animations. However, realism is not the only goal in fluid simulation, as film is a visually expressive medium, with a certain look, feeling and message to portray to the viewer. It is the task of an effects technical director (FX TD) to control and apply changes to the fluid animation, to fit with the desires of the director – in short, to art direct. When art directing a fluid animation, a FX TD will modify parameters and apply body forces, which often breaks with the real-life physics of the simulation, but is done to achieve the desired look and message of the scene. As such, realism and art direction can seem to be contradictory, however this paper investigates whether this is truly the case. Art directing fluid animations will necessarily break with the *physical realism* to some degree, but not necessarily with the *perceived realism*. This study will investigate the degree to which art directing and applying forces to a fluid animation, affects the realism perceived by the viewer.

Traditional animation is key-framed, and it is up to the skills of the animator to achieve the desired realism of the scene. The powerful computational power of modern computers has allowed for the creation of very accurate fluid simulations, like the computational fluid dynamics (CFD) used to test airplane designs and the likes. Fluid animation for films is based on the same formulas used for CFD, however with a simplified solver, since complete accuracy is not necessary, as it is only the final imagery that carries value. As such fluid animation place itself somewhere between the physical accuracy of CFD and the artistic work of the animator. This mixture allows for realistic looking fluid dynamics that are nonetheless still controlled by the FX TD, to achieve the desired art direction. It is however unknown to what degree the art direction will impede the perceived realism, if any at all, and this paper provides new insight into this question. To test this, three versions of a fluid animation was created for this study, with varying degrees of body forces applied. The most physically accurate of the animations only has real-life forces applied, like gravity, while the most unrealistic animation has several forces applied, in order to achieve the desired art direction. These animations have been shown to test participants, who provided feedback on the degree of perceived realism, as well as how effective the message of the scene is conveyed.

Previous studies have investigated the realism of physically based simulations, however rarely from the angle of the FX TD or animator. Body forces are the main tool afforded to the FX TD, to control the motion of the fluid, and a better understanding of how these forces effect the perceived realism is important, in order for him to know how to move on the spectrum between realism and art direction. Body forces have several uses, but is often used for art direction, by controlling the fluid to achieve a certain look, feeling and message to the motion.

This paper is intended for an FX TD or others working with the art direction of fluid animation. As such it is more interested in the tools provided to the artist and less so on the underlying equations and coding. While the solver provides the calculations needed to provide physical realism to a fluid, it is the FX TD who manipulates the fluid to achieve the final results. A lot of knowledge exists on the physical motion of fluids which are applied to the solver, however if the artists using the tools do not have a clear understanding of how they are affecting this, then the physical realism of the solver will be lost through the process. As such I find it useful to provide new insight into this part of the process, for the creation of fluid animation for film and TV. For the same reasons, are the animations used in this study created with many of the same complexities as an animation made for a real production. This of course provides extra variables than testing single parameters would, but is desired, as the intent is to provide results that can be translated more directly to film production.

The extent and complexity of the study does however provide certain limitations to the achievable results and thusly it is beyond its scope to provide clear tolerance threshold for each force. The intentions are rather to provide a more general understanding of the use of body forces and a knowledge and vocabulary that will help a FX TD in judging the impact that using forces will have on the perceived realism.

Fluid simulations are used for many natural phenomena, but this study will put a clear focus on liquids. Many of the body forces used in the study do however also function with smoke, fire or any other phenomena simulated by a fluid solver. As such the results can also be used to inform other forms of animation than just that of liquid.

## 1.1. HYPOTHESES

**HYPOTHESIS I**: Art directing fluid animation, by applying body forces, will lessen the level of perceived realism.

**HYPOTHESIS II**: Art direction can convey a desired feeling and message to the viewer.

# 2. BACKGROUND & RELATED WORKS

## 2.1. ART DIRECTION AND VISUAL FILM LANGUAGE

The work of visual effects artists can be seen as a continuation of the film work done by special effects (SFX) artists. While SFX artists create practical real-life effects in front of the camera, a VFX artist uses the computer to create the visuals. As such the VFX artist becomes part of a visual tradition and the language of cinema.

In VFX an effects technical director has the specialized job of creating animation that is physically based on reality. Mathematical equations that describe the movements of real life phenomena drives these animations and provide the foundation for the physicality and visually realistic behavior. The solver does however only provide the physical realism and it is up to the FX TD to provide the right feeling and meaning, on behalf of the brief provided by the film director. The *feeling* is the emotional response to the plot and visuals, while the *meaning* is the viewer's interpretation of what they see (Bordwell and Thompson 2013). It is of course impossible to control what the audience will feel and think, when watching a scene and it becomes even more speculative when the feeling is dependent on a visual element alone. How does a jagged ocean wave compare to a curved? The best a filmmaker can do is rely on conventions. As Bordwell and Thompson (2013) argue; works of art, including film, are human creations and the artists and viewers all exist in society and history. This means that the film will relate to the world and to other works of art and will be informed by tradition, styles and forms. These common traits are what Bordwell and Thompson call *conventions*. An artist knows how to use these conventions, but the viewer also knows how to read them. When the viewer responds to cues in the film, he will rely on his experience of life, as well as previously watched movies, to inform his overall perception. This means that film conventions rely on both real life, but also the history of film. When we see a car crash in a film, we expect an explosion and a large fireball, because this is how a car crash has been portrayed in film for decades. An FX TD will typically mimic these conventions of a car crash explosion, rather than trying to duplicate a real-life scenario.

Film is a stylized version of reality and the visuals need to fit the story and mood.

> Very often conventions demarcate art from life, saying implicitly, "In artworks of this sort, the laws of everyday reality don't operate. By the rules of *this* game, something 'unreal' *can* happen." All stylized art, from opera, ballet and pantomime to slapstick comedy, depends on the audience's willingness to suspend the laws of ordinary experience and to accept particular conventions (Bordwell and Thompson 2013, 56).

As this quote illustrates, conventions are also dependent on the form and genre of the film, be it drama, fantasy, science-fiction or a commercial. These aspects will greatly influence the expectations of the viewer. What might seem appropriate in a fantasy film would feel highly out of place in the social realistic drama.

Fluid animation has two aspects to it, the one being achieving realism and the other is the artistic styling. While the main function of CFD are to behave realistic, the end goal of fluid animation is to achieve the desired visuals. Sometimes the right visual are in fact the most realistic, but often the director wants to imbue the motion of the liquid with a certain look, feeling and message – what is called *art direction*. In Fluid animation, art direction affects the look, movement and physical behavior of the liquid, which can be controlled very specifically through the computer application.

## 2.2. REALISM IN IMAGERY

As with paintings, photos and other visual representations of reality, film and CGI is of course just that; representations. The purpose of CGI is in many aspects to be a very precise representation of reality, or in other words, to create imagery that is indistinguishable from real-life photography.
James A. Ferwerda (2003) reminds us that an image is not the object itself, but rather a visual representation of the scene and it will as such vary in the degree of realism it achieves. Ferwerda argues, that when assessing computer graphics there are three varieties of realism to investigate. They are as follows:

> **Physical realism** – in which the image provides the same *visual stimulation* as the scene.

**Photo-realism** – in which the image produces the same *visual response* as the scene.
**Functional realism** – in which the image provides the same *visual information* as the scene (Ferwerda 2003, 2).

Each of these varieties uses different standards for measuring, to determine if an image is realistic.
The criterion for physical realism, is that the image provides the same visual stimulation as the scene. This means that the image will have to provide an accurate point-by-point representation of the spectral irradiance values, at that viewpoint, in the scene (Ferwerda 2003). To realize this, the model must contain correct descriptions of the shapes, illumination and materials in the scene and the renderer needs the ability to accurately simulate the properties of light. A physically accurate scene is however not enough, as the display device also needs the ability to deliver the light intensities physically correct to the eye. The first two aspects are currently possible via physically based CGI creation and rendering, however conventional displays do not have the ability to reproduce the rendered light energies (Ibid.).

The second standard for computer graphics is photorealism, which, simply put, is to achieve the same realism as a photograph of a scene. However, as Ferwerda points outs, we then need to understand what it is that makes a photograph look realistic. There are many variables to this aspect, but he points to one specific way of defining photo-realism, which is that the image is photo-metrically realistic. Photometry is the measure of how the eye perceives light energy and as such this definition means that the image must produce the same visual response as the real-life scene, regardless whether the physical energy, coming off the image, is different (Ibid.).
In their study on this subject, Rademacher et al. (2001) investigate what makes an observer perceive an image as either photographic or computer-generated. To test this, they created several images that differed on aspects like shadow softness, number of objects and surface roughness. The test participants were then told that they would be shown a number of images, which would be either real photographs or computer-generated and asked to rate them as either “real” or “not real”.
The study showed that participants found smoother shadows more realistic as well as rougher edges to the models. There was however no statistically difference in the perceived reality when the number of objects were changed, nor when the object variety or the number of light sources differed.

The last aspect, that Ferwerda sees as a standard for realism in computer graphics, is functional realism. The measure for functional realism, is how well the image provides the same visual information as the scene. Ferwerda uses the term *information*, to describes how well the image provides info on the meaningful properties of the scene, such as size, material position, motion and shape, such that it allows the observer to make reliable visual judgements and perform tasks. In short; the degree of functional realism is dependent on how well it allows the observer to perform the task needed, and similar to how it would be performed in the real world.

As I began by saying, the purpose of using CGI in films, instead of any other means of representation, is to achieve a high level of realism. One way in which this is achieved, is by using physically based rendering (PBR), which is based on mathematical formulas that describe real life aspects like light bounce, fresnel, reflection, refraction etc. Physical realism is achievable in the renderer, but not in the current display technology. However, by applying real-life physics to the rendering of the image, a photorealistic image is achievable. This paper is interested in photorealism, as this is the highest level of realism currently achievable for CGI. As such, when the term *realism* is used throughout this paper to discuss the look of the animation, it is understood as the specification set forth by Ferwerda concerning photorealism.
This however only provides half of our understanding of realism for fluid animation. Imagery for film is not merely concerned with the realism of still images, but rather images in motion. Film and CGI has the ability to show representations of real life scenes in motion via animation. This however poses new challenges for achieving realism, especially when animating complex real-life phenomena like fluids. While PBR is used to achieve photo real CGI, physically based animation is used to achieve realistic motion. This is especially utilized for complex real-life phenomena like fluids, where the mathematical equations that describe real-life movement are applied to the animation.

## 2.3. REALISM IN FLUID ANIMATION

In classic non-physics based computer animation, the level of realism is entirely dependent on the skills of the artist. The animated objects are controlled by the artist who moves and deforms them between key frames.

Before physics-based solvers were a reality, the animation of fluids was done with non-physically based solutions like displacement maps. However, these tools often lacked realism and the need to simulate natural phenomena, like smoke, fire and water, created a level of complexity that is impossible for an artist to achieve on his own. In 1999 Jos Stam wrote in his Siggraph paper on fluids, why physics-based simulation was needed.

> Building animation tools for fluid-like motions is an important and challenging problem with many applications in computer graphics. The use of physics-based models for fluid flow can greatly assist in creating such tools. Physical models, unlike key frame or procedural based techniques, permit an animator to almost effortlessly create interesting, swirling fluid-like behaviors. Also, the interaction of flows with objects and virtual forces is handled elegantly (Stam 1999).

It was also around this time that the first physically-based solvers where created for use in the film industry These animations are built upon mathematical formulas, that describe the movement of real life fluids and are used in the algorithms of the fluid solver. A solver is the backbone of any fluid simulation application which applies the laws of physics, and as a result, this form of animating achieves a high degree of physical realism to the motion. The solvers all seek to solve the Navier-Stokes equations, which I will present in more detail in section 2.4. The way in which they solve these equations are different from one solver to the next and has evolved since the 90s, but it is however still the same Navier-Stokes equations that are used to this day, when simulating the physical behavior of fluid.

In the late 1990's the concept of realism in simulated reality was something the simulation community was grappling with. In a report from the Fidelity Implementation Study Group, they used the expression *fidelity* to describe the perceived realism and defined it as: "The degree to which a model or simulation reproduces the state and behavior of a real world object or the perception of a real world object, feature, condition, or chosen standard in a measurable or perceivable manner" (Gross 1999, 55).

I will be using the same definition of realism throughout this paper, when pertaining to the realism of the motion. I will however use the term realism instead of fidelity, as it is better understood by the general public and will be easier understood in the questionnaires. The fidelity requirements set forth by Gross, validates the system by measuring the level of realism against a referent, which can be the real world or some substitute and afterwards follows an evaluation of whether this level of realism is acceptable for the intended purposes of the system (O'Sullivan, et al. 2003). In section 3 I will present the referent used for the animations made for this study, while section 4 will provide the intended referent for the test participants.

While the solver provides a powerful basis for realism, the skills of the artist are still very much needed when setting up the scene. The artist needs to create the setup of any given animation and provide all the necessary parameters to the solver, before starting the simulation. The work of the FX TD can be divided into two parts; technical and art direction. The technical aspects are knowing the application and how to set up the simulation and what parameters to change for the specific animation. The role as art director is more about achieving a specific look, feeling and message. This could be a note from the director saying that the tidal wave needs to look more menacing, and then it is up to the FX TD to know which parameters to change to achieve this art direction. One large challenge to art direction is, that it often runs the risk of minimizing the level of realism and for that reason an understanding of how we perceive realism is invaluable.
The human perceptive system is not perfect in detecting the realism of physical systems. Several studies have shown weaknesses when it comes to detecting dynamic anomalies. Profitt and Gilden (1989) showed that people are good at detecting anomalies when only one dimension of kinematic energy is presented, but are less competent when judging more complex systems.
O'Sullivan et al. (2003) tackles the problem of evaluating the visual quality of animations, in which physical parameters have been distorted or degraded, either due to real-time requirements or intentionally for aesthetic reasons. In this study, participants where shown animations of two balls colliding, with variations applied to the physical realism in the resulting angular momentum and spatio-temporal distortions. The study showed that expansion of the angle was preferred over contraction and an increase in velocity, following a collision, was preferred to a decrease.
Han, Hsu, McNamara and Keyer examined the perceived realism or believability in fluid animation in the paper "Believability in Simplifications of Large Scale Physically Based Simulation" (Han, et al. 2013). Their findings show that it is possible to use approximated simulation methods, without the viewer perceiving the distortion caused. They also prove that it is

possible to fix object under a pile, without transformations, and keep the same level of visual plausibility.
These findings show that it is indeed possible to have a lesser degree of actual physical realism, without it affecting the realism perceived by the viewer. This investigation was mostly concerned with the degree in which it is possibly to lessen the computational power needed for the calculation of the fluid simulation and they show key areas where this is possible. My investigation is however not concerned with computational power, but rather to which degree a FX artist can manipulate with the physical realism to achieve a certain art direction, and still maintain a level of perceived realism.

My study is concerned with the intentional distortion of physical parameters, with a purpose of creating a certain feeling and message. In filmmaking, there are no real-time requirements. Fluid simulations and rendering does consume a lot of time in film production and as such there are steps taken to lessen the time consumption in order to meet the deadline. This is however nothing near of what is required of real-time simulations, like the ones used in computer games, with a loss in realism as a result. In filmmaking, the FX TD must also keep the time requirements of the animation low, but the number one focus is on the look and realism of the imagery. The emphasis on lowering computational load is more concerned with providing enough speed to the simulation, to allow the artist to interact and manipulate the fluid in a meaningful manner.

Section 2.4 will provide examples on how computational load is lessened for fluid animations in general, while section 3.2 is concerned with the animations made specifically for this study. The next section will focus on the technical aspects of fluid animation, and how the physics of real-life is translated into equations usable for the fluid solvers used in animation applications, where they can be transformed and manipulated by the FX artist.

## 2.4. THE TECHNICALITIES OF FLUID ANIMATION

Simulating fluid flow means solving the Navier-Stokes equations. These equations are named after the physicists Claude-Louis Navier and George Gabriel Stokes, who authored them in the 19$^{th}$ century. The equations are an expression of Newton’s second law, that have been applied to fluids. The equations describe the fluid flow and outputs a velocity field, and as such it does not provide a position value but rather velocity. It is an advection equation, which in fluid simulations is used to calculate how particles move within the velocity fields. The velocity field is a description of the movement of the fluid at any given point in time and space, and from the velocity field it is also possible to solve other aspects, like flow rate or drag force (Seymour 2011).

Fluid simulations require far less precision, than the CFD models used in the physics field, since their value is solely based on the visual output. As such the physical realism is not the only important factor, but also low computational power and controls and parameters that can be easily implemented and altered. The function of the solver is to apply physical realistic behavior to the fluid, but it should also allow for the speed and ease, necessary for artistic manipulation. To achieve this, the computational power needed by the solver is lowered, by leaving out certain aspects that are important in the physics field, but does not have a great impact on the realism of the visuals. Fluid solvers will typically assume fluid to be incompressible, meaning that the volume of the fluid is constant and homogeneous, or in other words, that the density in constant (Limtrakul, et al. 2010). In some cases, the solver will also leave out aspects like viscosity to further simplify the equations and computational load.

The computational power needed is greatly lowered when using these simplified Navier-Stokes equations for incompressible flow. The Navier-Stokes equations for incompressible flow states that mass times the acceleration of fluid (particles) is proportional to the forces acting on them. The particle acceleration is decided by the forces acting on it and the pressure on the liquid. High-pressure areas push on low-pressure areas. This means, that we only see an effect on the fluid particle, when there is an imbalance of pressure in the fluid. This imbalance can be measured, at the position of the particle, by the negative gradient of pressure (Bridson 2015). To integrate this over the volume of the fluid and thus getting the pressure force, we will multiply by the volume. The other fluid force to take into account is due to viscosity. In praxis, this force seeks to get the particles moving at the average velocity of the nearby particles.
In the Navier-Stokes equation, acceleration is due to gravity (-9.81 $m/s^2$). However, in animation, additional forces will often be applied. These forces are called body forces, as they are applied throughout the whole body of

fluid and not just the surface, and they are added into the equation, on top of gravity, as one combined force.

In 1996, Foster and Metaxas introduced the first comprehensive methodology for simulating fluid that was computationally possible and could be integrated into a solver. Navier-stokes equations are in the form of a vector field, so to create fluid simulations, we need to project to other systems to allow for computational ease of use. These systems are called *solvers* as they solve the equations, through various means.

## SOLVERS

Each application uses a different solver, but they all seek to solve the Navier-Stokes equations, with the goals of realism, speed and ease of use. The way in which the equations are applied are different depending if they follow the viewpoints of the French mathematician Joseph-Louis Lagrange or the Swiss mathematician Leonhard Euler. They present two different approaches to tracking the motion of a fluid: Langrangian and Eulerian.

Foster and Metaxas introduced the first method for fluid animation, using the Navier-Stokes equations and the Eulerian approach (Foster and Metaxas 1996). Instead of tracking each particle, the Eulerian method looks at fixed points in space and sees how the measures of fluid quantities, like density and velocity, change over time at these points (Bridson 2015). These fixed points create a three-dimensional grid, in which the fluid can move around.

The Langrangian approach uses particles to introduce change to the system. In this approach, the fluid is made up of a large number of particles, that each have assigned values like mass, density, pressure and velocity (Limtrakul, et al. 2010). A popular Langrangian approach for fluid dynamics, is the Smoothed Particle Hydrodynamics (SPH). This method was first created in the 1970's to handle astrophysical simulations (Gingold og Monaghan 1977) (Lucy 1977), but was later adopted by the VFX industry for fluid animation. The fluid application, RealFlow (1st edition), was the first to implement the algorithms into a solver that could be used in the film industry, back in 1998 (Seymour 2012).

RealFlow is still widely used in the industry to this day, and it is also this application, that I have used to simulate the fluids, for this study. RealFlow's solver has however evolved since then and today it does not exclusively use the Lagrangian approach. The Dyverso SPH used in RealFlow 10 (Next Limit Technologies 2016) is a hybrid solution between the particle-based Lagrangian and the grid based Eulerian approach. The advantage of using the Lagrangian approach is that it is very detailed in small scale simulations, however, it does not scale well and becomes slow in large-scale scenes, which have a high particle count. The computation for grid-based solvers are more efficient and allows for a much higher grid cell count than with particles. To maximize the advantages of both approaches, RealFlow uses a particle solver at its core with the second solver being grid-based. This hybrid approach is also sometimes called a fluid-implicit particle (FLIP) solver and is used in many applications for its scalability, precision and ease of use.

## CONTROL METHODS - BODY FORCES

To allow the FX artist to affect the flow and behavior of fluid animations, simulation applications contain several tools or forces to control the fluid. These can be in the form of values, that controls the physicality of the fluid, or body forces, that are added to the scene and affects the motion of the fluid.
Foster and Metaxas where the first to propose a methodology for controlling fluid animations in 1997. The values that change throughout a fluid simulation are generally; fluid properties, velocity field, boundary properties, and the internal and external pressure field (Foster and Metaxas 1997). This means, that these are the values that the forces can affect, when controlling the movement of the fluid. The forces allow the artist to control the fluid without knowing the underlying equations and the code of the solver. Instead these are meant to be effective and easy to use tools, that still seek to solve the Navier-Stokes equations, as physically correct as possible. The degree to which these forces are physically based differ, but they all seek to maintain the visual realism of the fluids movement. The physical realism is highly connected to how much the forces restricts and constrains the motion of the fluid. Unconstrained forces typically function as either attractors or repellers that push the fluid to or from the force, like a wind force or a noise field. The constrained forces limit the movement of

the fluid more, in order to have it follow a desired path or form a desired shape.
Limtrakul et al. (2010), divides forces into path defining and object defining controls. The path defining control allows the artist to define the movement of the fluid to follow along a line or curve. Depending on the application, the curve will often also have a radius assigned to it, that either constrains the fluid from moving outside of it, or limits the range of the forces - the latter being less restraining.
The object defined control will deform the fluid into the shape of an object, like a 3D polygon mesh. This is done by guiding the motion of the fluid into the form of a target shape. The artist is then able to control the degree in which the fluid keeps the shape and how much it can move outside the boundaries.

The forces presented are all 'invisible', in the sense that the graphics do not show the forces themselves but rather the resulting motion of the fluid. Objects, like the ice cubes in figure 3-4 also apply force to the fluid, but the source of this force, the ice cubes, are visible to the viewer. As such there is a one to one action and reaction, that the viewer can see. However, when I use the term force, it relates to the unseen forces applied by the artist to affect the motion. These forces are not directly visible to the viewer, and as such there are no explanation for the change in motion, from the point of the viewer. It is exactly for this reason, that applied forces run the risk of lowering the perceived realism, especially when the forces are highly constraining.

Without any additional forces applied to a scene, the solver will simply apply the Navier-Stokes equation for incompressible fluid with gravity as the force. This matches real life were the only invisible force is gravity, and possibly wind, and this setup is as such the most physically realistic. When applying extra forces, these will be applied to the Navier-Stokes equation on top of the gravity force and, with the exception of applying wind forces, this will necessarily break with the physical realism.

Body forces can be used with varying degrees of constraining the motion of the fluid. The more constraining a force is, the more it risks lowering the level of realism, and as such an understanding of this is crucial when balancing realism and art direction. Several forces were used in the fluid animations created for this study, which will be elaborated in section 3.2, on the implementation.

# 3. DESIGN AND IMPLEMENTATION

Three fluid animations were created for the study on how art direction affects the perceived realism. These animations are identical, except for the body forces being applied to the liquid, in each one. The purpose of the forces is to achieve various forms of art direction, and to study how this is perceived by the viewers and effects the degree of realism.
In this study, real-life is used as the referent for realism. In short, this means that if the animations where to be completely realistic, they would look photorealistic and the fidelity of the motion would appear to be physically accurate to real-life.

As mentioned, the number of forces applied to a fluid and the level to which they constrain the fluid will affect the real-life physical behavior. As such the animations with more forces applied to the fluid, are less physically accurate and this paper seeks to answer whether or not this also affects the realism that the viewer perceives.

The three animations have been named as follows, in accordance with the number of forces and degree of constraints, applied to them.

**Animation 1: Realistic**
**Animation 2: Semi-realistic**
**Animation 3: Unrealistic**

The following sections will present the design and implementation of these three animations.

## 3.1. DESIGN

The considerations, for the design of the animations, were all based on the intention of creating animations that could be used to test the hypotheses of the study. The first design consideration was simply that the animations should focus on a fluid animation, while the second was to mimic the overall form of films. The viewers of the animations are indirectly asked to detect dynamic anomalies, in the motion of the fluid, and on that behalf, judge the level of realism. Gilden and Proffitt (1989) have proven, that when the complexity of physical systems increases, people become less competent at noticing the dynamic anomalies, so the animation had to be simple enough to be easily read. However, some complexity is still maintained, as the purpose of this study is to examine fluid animation as it is used in film and TV, and as such should the videos mimic these mediums. The third consideration, is that the overall form of the video clip sets the conventions for realism, and because of that it should have a real-world setting. The last consideration was that the scenario should be able to function at either extreme of both realism and art direction.


*Figure 3-1, Bic Mac Bang (Maddison 2015)*

The intend of the animations, was to create a scenario that was easy to understand, primarily focusing on a fluid in motion. Simple in its expression but with enough elements to make the scene seem at home in different media forms. The main inspiration came from a commercial (Maddison 2015) showing ice cubes being dropped into a cup of cola, making the liquid splash (see Figure 3-1). Unlike the white abstract void of the commercial used for inspiration, a more realistic setting was chosen. This was done, so the conventions would match that of real-life more closely.

With these considerations in mind a scenario was created. The base animation shows a glass of cola placed on a wooden table, situated on a palm tree beach. As the clip starts, three ice cubes are dropped into the glass making the cola fluid splash into the air before landing on the table.

From this simple scenario, three clips were created, which vary in the degree of art direction. The art direction of the clips was intended to have two functions, the one being a more interesting and aesthetically pleasing motion to the fluid, and the other was to send a symbolic message. Figure 3-2 shows, how the animations have been designed, in regards to art direction, realism and forces applied. The forces (or daemons as they are called in RealFlow) will be further discussed in section 3.2 on implementation.

REALISM ← → ART DIRECTION

| | **Animation 01**<br>**Realistic** | **Animation 02**<br>**Semi-realistic** | **Animation 03**<br>**Unrealistic** |
|---|---|---|---|
| ART DIRECTION | Low<br><br>**Realism** | More aesthetically pleasing<br><br>**Feeling** | Aesthetics & message of love<br><br>**Feeling and meaning** |
| DAEMONS | **Fluid:**<br>- Dyverso Emitter<br>- Gravity<br>- Drag force<br>- K_isolated<br><br>**Ice cubes:**<br>- Gravity<br>- Wind | **Fluid:**<br>- Dyverso emitter<br>- Gravity<br>- Drag force<br>- Crown<br>- K_isolated<br><br>**Ice cubes:**<br>- Gravity<br>- Wind | **Fluid:**<br>- Dyverso emitter x 2<br>- Gravity<br>- Drag force<br>- Crown<br>- DSpline<br>- Filter<br>- K_isolated<br>- K_volume x 2<br><br>**Ice cubes:**<br>- Gravity<br>- Wind |
| REALISM | High | Medium | Very low |

*Figure 3-2, design of animations*

The animations have been designed to be at either end of the scale for realism, in a setup that is similar to that used in professional film productions. The main function of the animations is to have a varying degree of realism. Animation 1 is the most realistic, as it has no additional forces applied other than gravity. Animation 2 and 3 are increasingly less

physically accurate, as the number of forces applied to the fluid increases. The purpose for applying forces in a real production, would be to achieve a certain feeling or message, and as such I have applied the same motivation. The purpose for the art direction of animation 2 is as such, to achieve a more aesthetically pleasing movement by creating a symmetrical crown splash. The intention of this is furthermore to create a more pleasant feeling, regarding the liquid, when being viewed.
The forces applied to animation 3 breaks with the laws of physics and creates a swirling fluid that gathers into a floating heart. This art direction is intended to create a message of love and to connect this feeling back to the cola.

While the force of the ice cubes and the resulting splash was made as physically accurate as possible for animation 1, animation 2 is less realistic in this interaction. The intention for animation 2 was to have a more aesthetically pleasing result, by forming a crown splash, when the ice cubes hit the fluid. A crown splash happens when a force hits a calm fluid, causing it to splash up in a shape that resembles the outline of a crown. This fluid motion does happen in real life, however only under certain circumstances, like when a drop hits the calm surface of a fluid. First a ring will rise, and because of the surface tension, the edges will contract and form small droplets (Schlick, Daemons 2016).This kind of motion is quite aesthetically pleasing, because of its symmetry, and for this reason it is often used in fluid animations, even when it would not be physically accurate.
The splash in animation 2 is mostly caused by a crown force and not the force applied by the ice cubes. The splash is slightly more powerful, than in animation 1, as O’Sullivan, et al. (O'Sullivan, et al. 2003) have proven, that an increase in velocity is perceived as more realistic than a decrease.
Animation 3 is designed to have a very high level of art direction and little regard for realism. I wanted to test if the art direction would actually be understood by the viewer, by having a very clearly defined visual message. The heart shape is universally understood to be a symbol of love and I utilize this, by having it as a visual element that is easily recognized and with clear connotations. It also seems appropriate to this kind of animation, as it follows the visual of Coca Cola who have used the heart shape for commercials.

The scenario was also filmed in real-life to provide a referent for the dynamics. The use of this was limited, but it did provide a reference to which the fidelity of the animations could be compared to.

*Figure 3-3, Real-life referent*

The design of the animations is further elaborated on in the next section which will also go through the implementation process.

## 3.2. IMPLEMENTATION

Time was spent researching which applications to use for the animations, before settling on the combination of Maya (Autodesk Inc. 2016) and RealFlow (Next Limit Technologies 2016). RealFlow was chosen as it is the application with the highest number of tools for art directing fluid. It does however not offer support for modelling and the rendering capabilities are limited. As such, RealFlow was used only for the fluid simulation while the modelling, shading, lighting and rendering was done in Maya. Finally, for the post-processing of colors, depth of field, speed etc. the compositing suite Nuke (The Foundry Visionmongers 2017) was used.

The following sections will present the implementation process in chronological order, from modelling to simulation, shading, lighting, rendering and finally post-processing.

## MODELLING

All the geometry was created in Maya. This includes the glass, ice cubes, table and a heart model used for animation 3. The objects where created as polygonal quad meshes and afterwards triangulated, as this is a requirement for them to be used with RealFlow. The models where then exported as object files, using the .obj file format, to prepare them for use in the RealFlow scene.

## FLUID ANIMATION IN REALFLOW

RealFlow was chosen for the fluid simulation, mainly because of its many tools for art directing the movement of the fluid. RealFlow is used in both film and TV, but its many built-in body forces make it an obvious choice for commercials, were the physical realism often is more fantastical. The many forces, combined with the ease of use and speed of RealFlow, makes it a tool that is quite user friendly for the artists. To apply changes to a scene, a drag-and-drop system is used where emitters, geometry and forces can be dropped into the scene and the parameters can subsequently be changed through the “Node Params” window. Forces in RealFlow are a part of what the application calls *Daemons*. They categorize the daemons into three groups, where the body forces belong to group two and effects both particles, rigid bodies and soft bodies. The daemons in group one is used to remove particles from the scene and group three contains the remaining daemons, which have varying uses (Schlick, Nodes - Daemons 2015).

The objects were imported from Maya and set up in a RealFlow scene. The basic setup is the same for all the animations. The glass is placed on a flat surface and filled with fluid particles via a Dyverso emitter, and three ice cubes are placed above the glass. A gravity Daemon is added to the scene and initial velocity and rotational force is added to the ice cubes. When the simulation begins, the ice cubes rotates while falling into the glass causing a splash of the fluid particles. The ice cubes are set to soft bodies, to allow forces to act on them, while the glass and table surface are rigid bodies, which allows the fluid and ice cubes to interact with the geometry, but does not let the daemon forces move them. The overall cell size scale was set to 0.1, the FPS output to 120, minimum substeps was at 25 and maximum at 80.

## Animation 1 – Realistic

The first animation has the least art direction and as such the fewest forces applied. The clip simply shows the ice cubes being dropped into the glass and creating a splash.

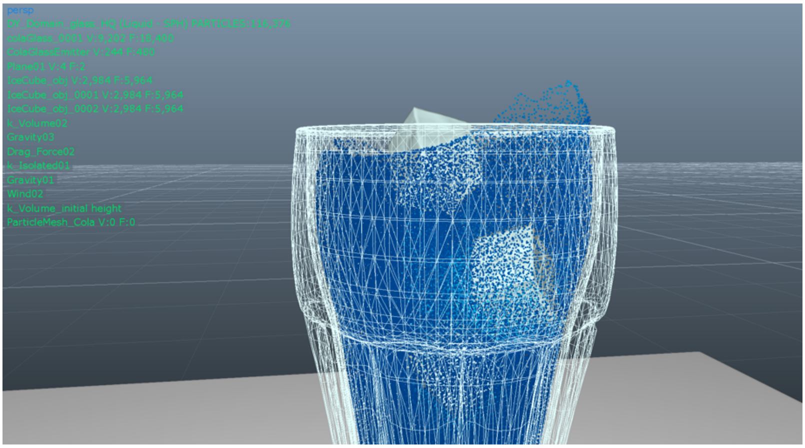


*Figure 3-4, RealFlow simulation of animation 1*

The simulation is kept as simple as possible, with only a few non-constraining forces applied, which mimics the forces a liquid would be affected by in real life. Gravity was applied to the simulation, as well as a drag force daemon, that provided external air drag to the fluid. An air daemon was applied to the ices cubes, to provide them with a bit more randomness in their movement, however, it was not applied to the fluid, to keep the complexity down.

*Figure 3-5, Final render of animation 1*

Except from gravity, the ice cubes are the only force that applies pressure to the particles and create the resulting motion of the fluid. The *DY Interaction factor* of an object controls the level of influence, that it will have when interacting with the fluid, and how much turbulence it will create. This value was set to 1 on the ice cubes, for this animation.

## Animation 2 – Semi-realistic

Animation 2 was identical to the first one, except for two very influential parameters. The interaction factor of the ice cubes was dropped to 0.5, which means that the influence, that the ice cubes have on the fluid, is half as much as in animation 1. Instead the splash is mainly created by a crown daemon. The crown daemon consists of several forces built into one, making it easy to use by the artist. The daemon combine both directional and shape forces, as well as a sheeter daemon. The effect is that the fluid is directed upwards in the shape of a crown, while the parameters chosen controls the edges of the fluid, tendrils and drops. The built-in sheeter daemon will introduce new particles to the fluid, in order to fill holes and keep the fluid shape from being torn.

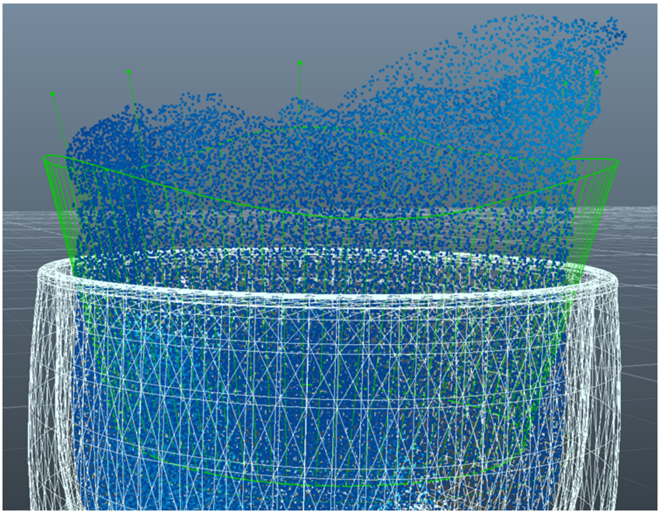

*Figure 3-6, RealFlow Crown daemon, applied to animation 2*

I timed the daemon to apply the forces shortly after the first ice cube hits the surface. This means that the main force applied to the fluid is actually from the crown daemon, which is invisible to the viewer, and not from the ice cubes themselves. This means that the splash is not very physically accurate as several forces, that are external to the ice cubes, are applied, in order to achieve the motion. The crown daemon even introduces new particles into the animation, which means that liquid will appear into existence, out of nowhere.

*Figure 3-7, Final render of animation 2*

I did however still try to keep a somewhat realistic look, by not making the crown shape too ‘perfect’ looking, and also by maintaining some of the interaction factor of the ice cubes. The animation is a compromise between realism and aesthetics, and as such could have gone further in either direction.

### Animation 3 – Unrealistic

Animation 3 contains the highest level of art direction and forces applied, and the lowest intend of realism. Apart from creating a scenario with less focus on realism, the aim was to keep the aesthetics of version 2 and add a more defined message on top. The first part of the animation is the same, as version 2; the ice cubes hit the glass and the fluid splashes up in a crown shape. However, when the crown splash is on its highest, a part of the fluid continues upwards, in a spiraling motion. The fluid then swirls around in the air in a circular motion, before ending up above the glass, where it slowly forms into the shape of a floating heart.

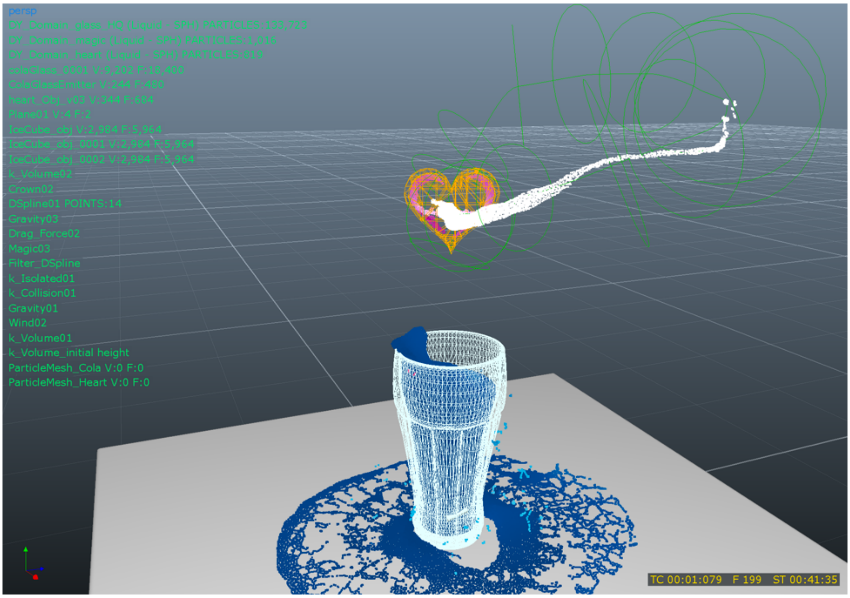

*Figure 3-8, screenshot of the RealFlow simulation for Animation 3. DSpline is seen in green and heart shape in yellow.*

Animation 3 had the same basic RealFlow scene setup, as animation 2, regarding the ice cubes and crown splash. But on top of that, several additional forces are controlling the fluid. As the fluid splashes up, a part of it comes into contact with a DSpline daemon, which propels the liquid upwards and swirling around in a circular motion. The DSpline affect parameter was set to *force,* which accelerates the particles, so that they move increasingly faster, as long as the force is acting on them.
The DSpline daemon creates a force field along a customizable spline, and along that path, you can add several control points (CP's), with individual settings for vortex, axial and radial strength (Schlick, Daemons 2016). The vortex strength adds rotation to the fluid, around the center of the spline, while the axial strength creates a force pushing the fluid along the path. The radial strength also adds force to the fluid, but around the control points and in the direction which they are pointed. The size and direction of the control points can be controlled via the handles and diameter settings. These controls where dialed in, though trial and error, to create a motion, that kept the fluid following the path, and at the same time was looking aesthetically pleasing.

*Figure 3-9, Final render of animation 3*

After swirling up in the air, the fluid ends back up above the glass, where the particles are killed, when coming into contact with a *K Volume* daemon. At the same time as the first particles are killed, another DY_emitter begins introducing new particles. This Dy_emmiter (named heart emitter), is placed exactly where the dSpline fluid is being killed, and the shape of the particles are constrained by an invisible heart object. As the fluid of the DSpline disappears from view, the heart shape is filled up, giving the illusion that it is actually the DSpline fluid that transforms into a heart shape.

## SHADING, LIGHTING AND RENDERING IN MAYA

The simulated particle flow was exported from RealFlow, to be used in Maya. The fluid mesh was then imported into Maya as sequential alembic meshes. The animated ices cubes where imported as well, via the RealFlow Maya plugin. This allowed for the next step of the process, which was the shading of the objects.

The shaders are all created as V-Ray materials in Maya and wherever possible, real life values are used. For instance, was the refractive index of the objects set to real-life values, with the glass set to 1.523, ice 1.310 and liquid 1.330. The shaders for the glass and cola were completely procedural, while the table also utilizes textures as well as physically-based rendering maps for the diffuse, displacement, gloss, normal and reflections. As it has been proven that rougher surfaces are perceived as more realistic (Rademacher, et al. 2001), this attribute could have been utilized to create more realistic shaders e.g. by applying dirt maps to the glass. This would however only enhance the photorealism, which is not the main focus of this study, but rather the fidelity of the motion of the fluid. The focus is put on the fluid and as such it was not considered necessary to apply dirt maps and the likes, to the objects. A wetmap was not considered necessary either, but as the results will show, this had a high impact on the realism.

As both a light source and reflection environment, a 360° high dynamic range (HDR) image of a beach was used (see Figure A-2). The image was used for image-based lighting (IBL), which uses the color information and light intensities of the image to light the models, which creates a very detailed and natural lighting that matches the visible scene. The color temperature of the light, from the IBL, was set to 5500 Kelvin, to match that of a summer sun. The image was also used for reflections and refraction, which is especially relevant for the glass, since the shading primarily consists of these two factors.
A V-ray Sun was also added to the scene to allow for a more fine-tuned control, than the IBL allows for. Rademacher et al. (2001) have demonstrated that smoother shadows are perceived as more realistic and to achieve that, the size multiplier of the sun was set to 20.

V-Ray 3.4 (Chaos Group 2016) was used to render the images as multilayered exr image files. The resolution of the images was set to 2560x1440 pixels, to match the settings recommended by YouTube, for 1440P videos. Progressive rendering was used and the max render time was set to 2.8 minutes. Render time is a compromise between time and image quality, and 2.8 minutes provided an image with an unnoticeable amount of noise and artifacts, and a render time of approximately 18 hours, for each animation.

## POST-PROCESSING IN NUKE

The post-processing in Nuke was mainly done to enhance the aesthetics of the visuals and also to add further elements, that are normally applied to animations made for film. The saturation, hue and grading was changed to enhance the colors of the animation. Depth of field, chromatic aberration,

grain and a vignette was added, as this is likewise a part of the general workflow for CGI. In film-production this is done to make the CGI look less 'perfect' and to match the real-life photography with all its imperfections. Two palm trees were also added, in between the table and the environment image, to provide dimensionality and a sense of depth to the scene. Finally, I attempted to darken the table, where the fluid had come in contact, as to simulate wetness. This did however not produce very convincing results and a much better approach would have been to use a wetmap in Maya.
The images below show an example of the animation directly from Maya and after the post-processing in Nuke.

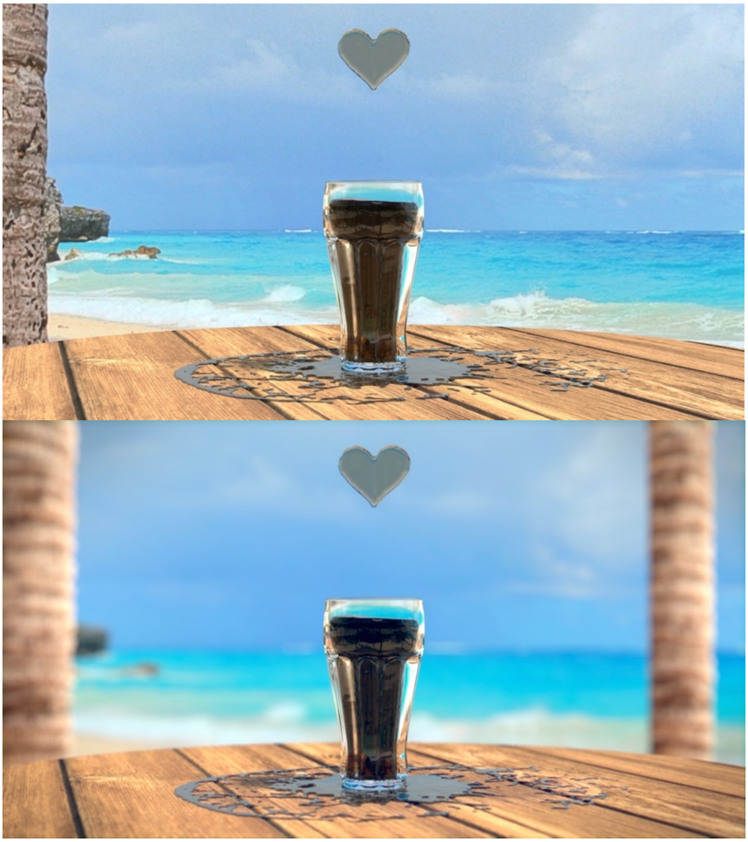

*Figure 3-10, A: Render from Maya (top), B: Render after NUKE post-processing (bottom)*

The animation was retimed to be 3.33 times slow motion, played back at 24 frames per second (FPS). 24 FPS is the standard for feature films and was used for this reason. This resulted in 228 frames, that were rendered as a 9.5 seconds long .mov video file, with the Apple ProRes codec.

# 4. USER STUDY DESIGN

In order to test the perceived realism of the art directed fluid animations a user study was created. The study was designed as an online questionnaire, that could be accessed through a standard web browser. This allowed the questionnaire to be easily distributed via a link. This also meant, the participants were to watch the animations on their own device and unobserved. Because of this, every participant is asked to provide information on their device, to see whether this has any influence on the perception.

The animations were all uploaded to YouTube, to ensure easy playback on every device. They were uploaded in the original resolution of 2560 x 1440 pixels, however the device and network speed of each participant will ultimately decide the resolution in which YouTube plays back the video.

The study was designed as an online questionnaire with both qualitative and quantitative questions. The entire questionnaire can be seen in the appendix Figure A-3. Six different versions of the questionnaire were created, whereto the only changing factor is the order in which the animations, and corresponding questions, are presented. This avoided order bias by ensuring that the participants were subjected to every one of the six possible orders. A landing page was created in order to provide a single link to the participants, that would then subject them to any one of the six questionnaires. The landing page used a javascript code (Figure A-1, in the appendix), that randomly redirected the participants to one of the questionnaires.

The user study uses a within-subjects design, where each participant is shown all three animations. Eye-gaze was not used as a measure for the study, as Han et al. (2013) has proven this to not be a viable measure. The quantitative questions were all asked on a 7-point Likert scale.

## Questions

The first page of the questionnaire provides the participant with a short introduction to the subject of the study, as well as the basic information needed to understand the questions that follows. Participants are told that the project is regarding realism in computer simulated liquid. They are also told that *realism* should be understood, as whether the fluid looks and behaves like it would in real life. As such the referent, that the participants are asked to compare the animations to, is real-life. They are also, told that the following questionnaire-pages will present them with video clips and instruct them to subsequently answer questions pertaining this video. Besides from this basic introduction, the participants are naive to the further details of the study. The term realism can be understood in many ways, and as such it was necessary to present a common understanding to the participants on how the term is used in this study.

The participants were informed that all the videos are in slow motion, to ensure that this parameter did not influence their decision making. They are also told to watch the video as many times as they feel is needed. This instruction is provided, so that the participant can watch the short video enough times to feel, that they have a proper perception of the animation. The other reason, is that participants are performing the study on their own and unobserved, and as such it would be impossible to ensure that they only watched the video once. The informative text and the questions where provided in both English and Danish.

The next page provides the participant with the first questions. This section is pertaining age, gender, whether the participants have done professional work with CGI, and on what device they are watching the fluid animations. The next three pages are each regarding one of the three animations and are concerned with the perceived realism of the fluid and the message of the video. The final page asks the participant which animation they found the most realistic and which one the least, and finally if they have any further comments.

Each of the three pages with animations contains the same structure and line of questioning. Each page asks the participant to first watch the video (in full screen), via the link provided, and then return to the questions, which are all regarding the liquid in the glass. This information is provided, to ensure that the participants are not concerned with other factors than the liquid, when answering the questions.

After watching the animation, the participant is asked "Do you feel that the fluid looks realistic?" and allowed to answer on a Likert scale from 1 (completely unrealistic) to 7 (completely realistic). The choice of an ordinal

scale, instead of dichotomous, was to give the participants more options and provides a more detailed response.
This question relates directly to the main goal of this study which is to measure the perceived realism of the animations.
Even though the initial definition of realism and the instructions to focus on the fluid, tries to limit the understandings of the question, it is still impossible to control how the study participant will understand it and if they focus on the colors, reflection, refraction, movement or some other parameter.
The next questions asked, tries to limit the interpretations and focuses on the physicality of the fluid.

"Do you perceive the movement of the fluid as being physically correct?". While the former question was more general in its inquiry on realism, this question puts focus on the physicality and fidelity of the fluid. The reason for this, is that the only aspect that changes between animations are the forces applied and the resulting movement of the fluid. The shading, lighting, modelling etc. remains the same, and as such I wanted to focus on the physical behavior of the fluid, with this question. While the first question included photorealism, this question is more focused on the fidelity of the fluid motion.

"Did specific aspects of the visuals seem unrealistic to you?" was asked as a qualitative follow-up question, which allowed for a short written answer. This question provided insight into what the participants where addressing, when providing a lower rating in the previous questions. It also helped to tell, whether the rating was actually due to the forces being applied to the fluid, or some other element.

"Do you feel like the video contains a message?". While the previous questions where all pertaining the perceived realism, this question addresses the art direction. As mentioned, art direction is used to create a certain feeling or message, directed at the viewer. The intend with this question was to see, whether the participants actually experienced a message in any of the animations. A common human response is to create meaning out of everything, even when non is intended by the sender (Bruni og Baceviciute 2013). The question is mostly aimed to see if a message was perceived in animation 3, however, the aesthetics of animation 2 could also possibly be perceived as sending a message. The participants were furthermore asked to describe the message, if they felt one was present.

This was asked to see if the perceived message matched the one intended by the art direction.

The final page of the questionnaire asks the participant to choose the animation they found the most realistic and afterwards the one they found the least realistic. The function of these questions is to validate the former responses regarding realism. Do participants actually choose the video with the highest scores, in question one and two on each animation page, to be the most realistic, and vice versa? This also helps to validify the questions, as proper measures for realism.

Finally, the questionnaire asks if the participant has any further comments, to allow for feedback of any kind.

The fluid animations vary by the level of forces applied - which is done to achieve a certain art direction - while the remaining factors are held at a constant. If there is a statistically significant difference between the perceived realism, from one animation to the next, then a causal relationship can be claimed between the art direction and the subjects' responses. The responses to each single animation is of little interest on their own. What matters is how the participants' response pattern changes between animations and the dimensions of interest, i.e. how real they perceive an individual fluid animation to be is not of interest, only how real they perceived it to be, when compared to another, that differs on the level of forces applied.
All other aspects of the animation than the forces applied to the fluid are kept the same, to ensure that the only changing parameter is the movement of the fluid. This ensures, that any statistically significant differences in the viewer responses have a causal relationship to this parameter.

The goal is to verify hypothesis I and II, and to investigate factors that might affect the results. I will leave it up to further studies, to investigate the individual parameters in detail and detect tolerance threshold for each force.

# 5. RESULTS

A total of 114 participants took part in the study, evenly distributed amongst the six versions of the questionnaire. Of the 114 participants, there were 56 women and 58 men, between the age of 16 and 61 years (M=30.61 years, SD=11.362). Lærd Statistics was consulted during the statistical analysis (Laerd Statistics 2015).

## 5.1. REALISTIC LOOK

"Do you feel that the fluid looks realistic?" was asked on a Likert scale from 1-7. The data was treated as ordinal and a Friedman test was run to determine if there were any differences between conditions (Laerd Statistics 2015). Pairwise comparisons were performed in SPSS statistics with a Bonferroni correction for multiple comparisons. The degree of perceived realism was significantly different between animations $\chi^2(2) = 29.119$, $p < .0005$. Post hoc analysis showed, that there were statistically significant differences, in the perceived level of realism, from animation 1 (Mdn = 4.52) to animation 3 (Mdn = 3.71) ($p < .0005$) and animation 2 (Mdn = 4.27) ($p = .020$) to animation 3, but not between animation 1 and 2.

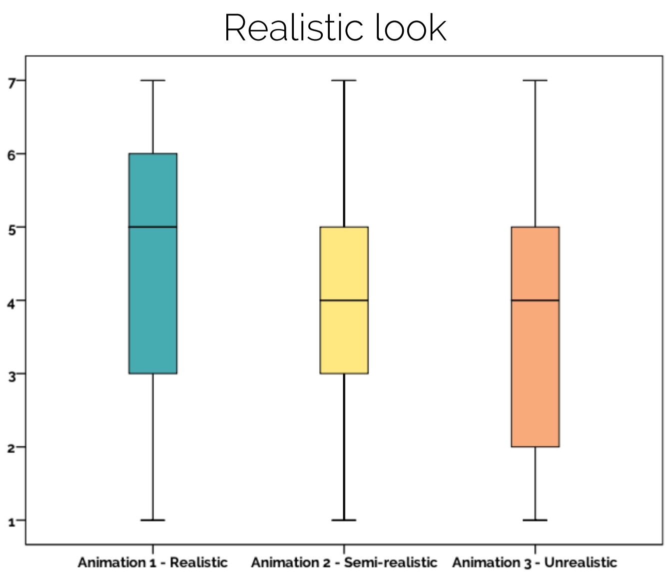


*Figure 6-1, Realistic Look*

## 5.2. PHYSICAL ACCURATE MOVEMENT

”Do you perceive the movement of the fluid as being physically correct?” was asked on a likert scale from 1-7. Again, a Friedmans test was run, to test if there were any differences, between conditions, regarding the perceived realism of the physical movement. The test showed, that there were statistically significant differences between conditions $\chi^2(2) = 92.792$, $p < .0005$. Post hoc analysis showed, that there were statistically significant differences in the perceived level of realism, from animation 1 (Mdn = 4.57) to animation 2 (Mdn = 3.92) ($p = .008$) and animation 1 and 3 (Mdn = 2.58) ($p < .0005$) and animation 2 to 3 ($p < .0005$).

Physical accuracy

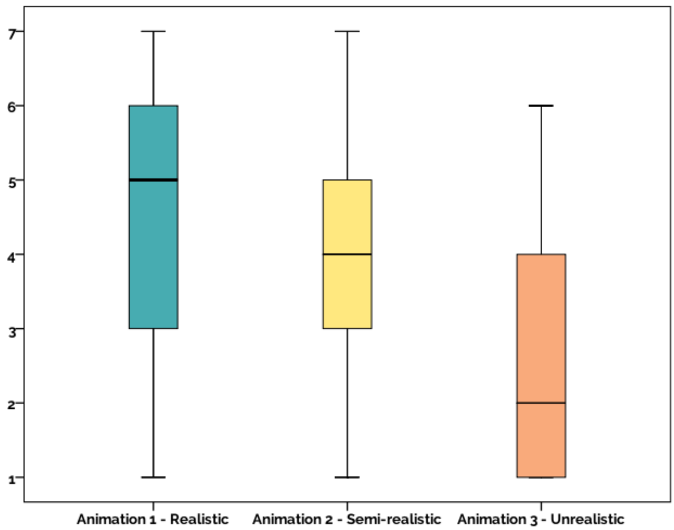


*Figure 6-2, Physical accuracy*

The mean score for animation 3 was furthermore calculated to be 3.18, for the respondents, who saw it as the very first video and for the remaining participants, who saw it as the second or third video, it was 2.28.

## 5.3. MOST AND LEAST REALISTIC

The last page of the questionnaire asked the participants to choose which one animation they found the most realistic, and afterwards which one the most unrealistic. 62.28% found animation 1 the most realistic, 23.68%

chose animation 2, 7.89% said animation 3 and 6.14% responded that they did not know, which one they found the most realistic.
To the question of choosing the most unrealistic, 10.53% responded animation 1, and another 10.53% said animation 2, while 74.56% felt that animation 3 was the most unrealistic. 4.39% (5 participants) chose the option “Don’t know”.

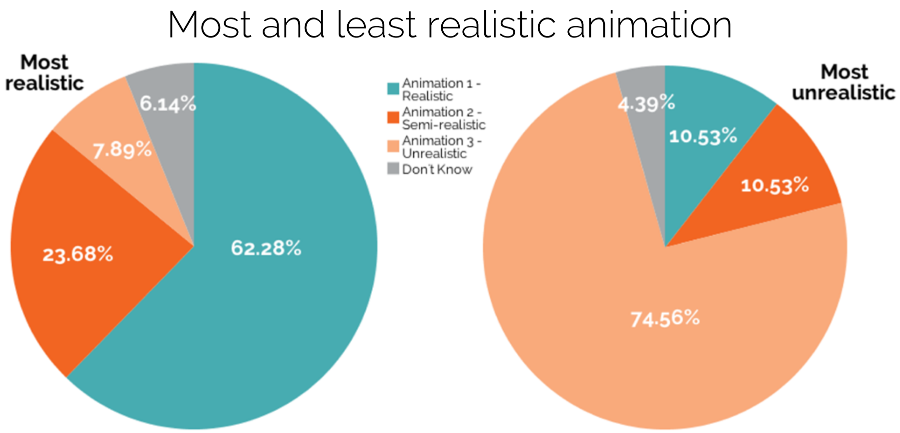


*Figure 6-3, A: Most realistic (left), B: Most unrealistic (right)*

## 5.4. UNREALISTIC ASPECTS

The responses from the participants were grouped according to the aspects each one mentioned. To only allow for one answer per participant, the responses were grouped according to the feature that the he used the most words to describe. If this could not be determined it was assumed, that the aspect first mentioned, was considered the most unrealistic by this participant, and then grouped accordingly.
All the responses where read and the recurring answers were grouped together, while the rest were grouped under “other”. This created the groups, that can be seen in Figure 6-4.

The low number of answers for animation 1 and 2, means that the results will be presented as number of people instead of percentages.

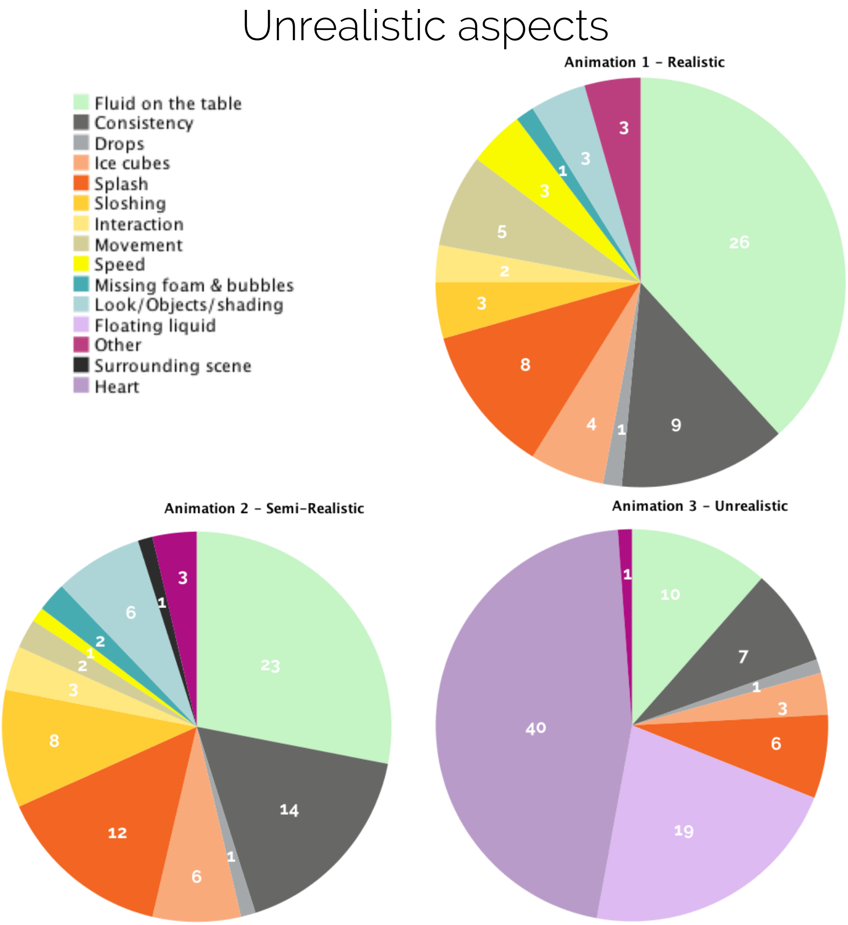


*Figure 6-4, Unrealistic aspects*

A selection of representational (unedited) responses are presented below.

**Animation 1 - Realistic**

- looks like quicksilver on the table
- It looks like the fluid had a higher viscosity than it should have, but I can't tell because you do not say what liquid you are trying to simulate, although I would guess that it is Cola. Therefore it can be a bit hard to say if it looks unrealistic or not.
- It seemed abit over the top. To much motion in the splash, or maybe it was due to the fluid looking very solid

- It looked slightly less thick this time, but with all the sloshing I would expect the glass and the table to appear wet. The liquid itself behaves more like I would expect mercury to. Oh, and the icecubes sink like rocks.
- Fluid hitting the table did not seem realistic

**Animation 2 – Semi-Realistic**

- The initial presentation made it appear like cola or similar soft drink, but the motion made it seem thick, and the table surface appeared hydrophobic. At approximately 0:06, on the visible right side of the top edge of the glass, a small amount of liquid hangs slightly over the edge, then crawls back into the glass. This is reminiscent of gel.
- It looked a bit too dark, and its interaction with the table seemed very unrealistic
- The right side of the liquid, looks like sludge rather than liquid on the edge of the glass. A more viscous liquid.
- The splash pattern on the table. The height that the fluid got when the cubes were thrown in.

**Animation 3 - Unrealistic**

- First of all, those are some heavy-ass ice cubes, splashing the drink this high. As of that snake like movement, which ends up in heart shape... I'm sure that everybody would take it as artistic choice, and it's pretty..... I forgot the term...... It's done alright, and viewer would choose to accept this unrealistic phenomena as diagetic within that fantasy world.
- The fluid dancing around before forming a heart-shape

## 5.5. MESSAGE OF THE ANIMATION

The participants of the study were asked in each condition, whether they thought that the animation contained a message. They could answer yes or no and as such the variable was considered dichotomous. Cochrans Q test was run to determine if the participants experienced a difference between the three conditions. The sample size was large enough to use the $\chi^2$-distribution approximation. 27.2% of the participants said that animation 1 contained a message, 26,3% said that animation 2 contained a message and 69,3% said that animation 3 contained a message.

The number of participants, who said there was a message in the animation, was statistically significantly different between conditions $\chi^2(2) = 79.763$, $p < .0005$. Pairwise comparisons were performed via Dunn's procedure with a Bonferroni correction for multiple comparisons. The adjusted p-values are presented.

There were a statistically difference between animation 1 and 3 ($p < .0005$), and between animation 2 and 3 ($p < .0005$), however no statistically difference between animation 1 and 2 was found ($p = 1.000$).

Further examination was done to see if the number of participants, who said that the animation contained a message, was different when animation 3 was the first they were exposed to. A simple calculation of distribution was performed. Of the participants who saw animation 3 as the second or third video clip, 73.68% said it contained a message. Of the participants who saw animation 3 as the first clip, 60.53% responded that it contained a message.

The participants who answered "yes" to the clip containing a message, were also asked to describe that message. This question was not mandatory and the number of answers was 32 for animation 1, and 29 people answered this question for animation 2. 79 participants had responded, that animation 3 contained a message and out of those 79 people, 74 elaborated on what that message were.

Except for a few deviants, the majority of the answers could be gathered into groups. These groups are based on recurring answers, while the unrepeating answers are grouped into the category "other".

Because of the low number of responses in condition 1 and 2, the results are shown in number of people instead of percentages.

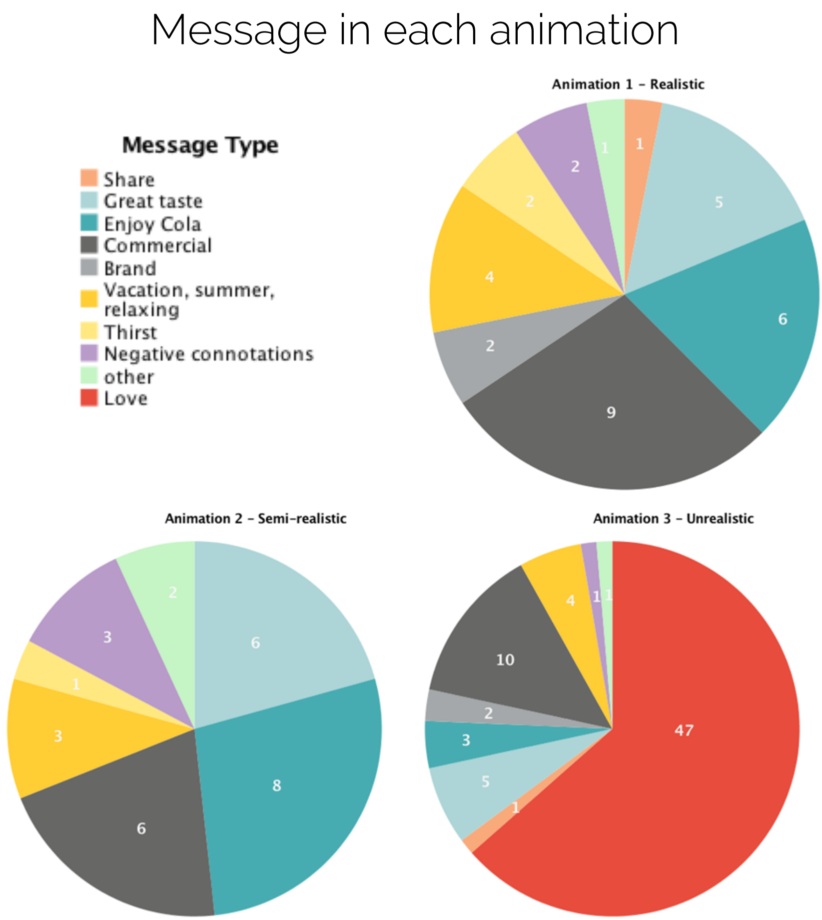


*Figure 6-5, Message type*

The following comment, describes the general themes of the responses, quite well: "Could be a summer AD for Coca-cola with references to the refreshing flavor of it and the love that cocacola [*sic*] uses for their commercials."

## 5.6. DEVICE

Since the participants experienced the animations on their own device, it was relevant to see whether this device had an impact on the perceived realism. 17.54% used a desktop computer, 50.00% used a laptop, 26.32% a smartphone, 5.26% used a tablet and 0.88% (1 person) responded "other device", but did not specify which. Of these devices, the highest difference

in resolution and screen size is between the smartphone and the desktop/laptop computer.
A simple test was performed, that compared the mean value of the perceived level of realism (question 1 on each condition page). The cumulative mean value for all three conditions were 4.17, when asking about how realistic the fluid looks. The mean value for smartphone users where 4.34 and for user of desktop/laptop computer it was 4.05.

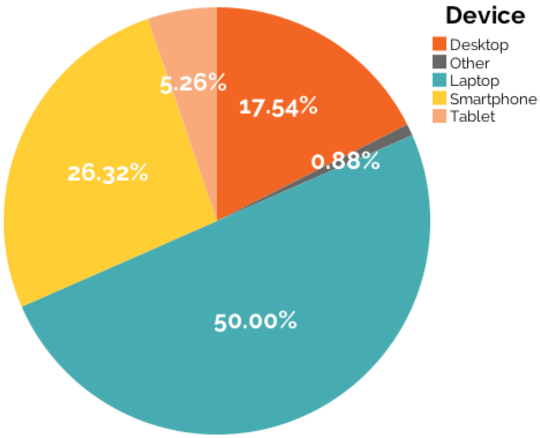


*Figure 6-6, Device*

Further statistical analysis was not performed, as an in depth study, of the effect that the device has on the perceived realism, is beyond the scope of this paper. The interest was to see if the big difference in screen size, between phone and laptop/computer, provided differences to the perceived realism, which it did but only to a small degree.
The meaning of this, and all the other results, will be discussed in the next section.

# 6. DISCUSSION

The purpose of this paper is to provide a FX TD, or others working with the art direction of fluid animation, with a better understanding on how the use of body forces, influences the perceived realism. Art direction is used to achieve a certain look, feeling and message and it encompasses all aspects of the visuals. This study will however focus on the motion of the fluid and how adding forces affects the fidelity of the liquid. Body forces are the main tool that a FX TD has to control the fluid, but these can be used with varying degrees of realism and an understanding of how you achieve the intended art direction, but still maintain the desired level of realism, is crucial, when you want to match the overall form of the medium. Is the animation intended for a commercial, fantasy film or a social realistic drama? This will form the conventions and expectations of the audience, which the FX TD needs to match.

The study also examines how the art direction is perceived and if the intended message is understood. To this regard, the user study was used to provide new insight into how physically based animations are seen. The results show how the three animations were perceived, regarding these parameters, and the following sections will discuss the results, as well as the study in general.

## 6.1. THE STUDY

The user study was designed to be accessible online, via a standard web browser, to heighten the likeliness of a high number of participants. This allowed the study to be easily shared and the participants were allowed to go through the study on their own and on their own device. The lack of oversight does however provide some changing variables and lack of control. The main variable that changes, is the device each participant is using to see the animations. Because of that, every participant was asked to provide information on their device, to test whether this has any significant influence, and the device used does seem to influence the perceived realism by a small amount. The use of a within-subjects design should however eliminate the drawbacks of letting participants use their own device. This design means that any variables added by the device of the user, will be applied across all the animations. One participant, using a smartphone, remarked that “It looked a bit too dark…”, which could easily be caused by low light settings on the phone. This factor would however be applied across all three animation and equally affect the perception that the viewer had. This is also the case for resolution, screen size, dynamic range etc. The device used will influence all these aspects, but the variables are then applied to all three animations, eliminating the problem. Nowadays, media is being watched on all kinds of devices, but it is beyond the scope of this study to test in depth how it influences realism. This study is concerned with the level of perceived realism, when comparing the animations, and less so on the realism of each one individually. Not much regard is put into how the individual animation scored, but rather how it scored, when compared with the others. Furthermore, the study will focus on the motion of the fluid (fidelity) and less so on the overall look (photorealism). What the user sees is of course all visuals, but it still makes sense to make a distinction between the look and the movement, i.e. the realism of the models, shading, lighting and rendering vs. the realism of the motion of the liquid. This distinction is important for this paper, as the variables that are changed between animation conditions, only apply to the movement of the fluid, by applying forces and changing parameters. The main interest of this study is to see how these changes affect the overall perception of realism, without explicitly telling the participants to focus on the motion alone.

A between-subjects design would have been desirable when asking whether the animation contains a message. Simply by asking the question it is likely that it will lead the respondent to think that a message is present and additionally the respondent is likely to compare animations as part of his decision making. This is undesirable as I do not wish to know whether one animation seem to contain a message, when compared with another, but rather how it is perceived on its own. To this regard, it would be better to have the participant only watch one animation and respond to this video in isolation.
The study participants are also likely to compare animations when judging the realism, even though they were told to use real-life as a referent and not one another. When you watch a fluid animation in a film, you will not be presented with another similar animation to compare it to, but only have real-life experience and to some extent prior animations, as a referent.
I ask the participants to compare the animations to real-life, but since this is a within studies setup, they will unavoidably also compare with the

previously watched animations. This means that the animation they watch first will use real-life experience as a referent, and set the base level, from which the following animations will be judged.
No matter if a within- or between-subjects design had been used, the video itself would influence the laws of physics, according to its overall form. As Bordwell and Thompson argues, the form decides the conventions and set the laws of physics. In a between-subjects design, the participants only watching animation 3 would likely perceive the clip as magical realism and as such the referent would be commercials or fantasy film. On the other hand, the participant only watching animation 1 might judge it according to real-life. This would pose a different set of laws for reality, for each animation and askew the answers. As such a within-subjects design is desired, as this ensures that perceived laws of physics are the same for all animations.

## 6.2. REALISM

As expected, the results showed significant differences, between animation 3 and the other two animations, when asked if the fluid looks realistic (question 5.1 in results). This was expected since the highly constraining body forces used in this animation, create a fluid motion, that is far from physically accurate. Animation 1 achieved the highest score (higher being more realistic) with a median of 4.52, while animation 2 had a slightly lower median at 4.27. The participants found animation 3 to look the least realistic, as it received a median score of 3.71.
The wording of this question was deliberately kept fairly open to interpretations. This allowed the participants to answer based on their overall opinion and according to their desired area of focus. However, the question asks about the *look,* and as such it is likely, that many participants will judge the animation according to the level of photorealism, and while this a valid measure for the perceived realism, it does not address the independent variable of the animations, which is the body forces. Objects, shading, lighting, rendering etc. are all the same between animations, and as such the photorealism remains the same as well. The main aspect, that changes between animations, is the forces being applied to control the motion of the liquid. This means, that any significances in the response pattern have a causal relationship to this parameter.

To address this more directly, the following question asked if the movement of the fluid was perceived to be physically correct (question 5.2 in results). The median for animation 1 was 4.57, animation 2 had a median of 3.92 and animation 3 had a median of 2.58. A Friedman test showed significant differences between all animations, but especially between animation 3 and the others. The low score for animation 3 indicates that the participants did indeed respond to the motion of the fluid, when answering this question, and its physically improbable use of forces. The focus on the fidelity of the liquid provided a higher difference in scores between animations, than question 5.1 did, and furthermore the scores were significantly different between each condition. This means, that the perceived level of realism was significantly different between each animation, with animation 1 being the most realistic with a score of 4.57, while animation 2 was less realistic with a 0.65 lower point-score, and animation 3 scoring almost two full points (1.99) lower than animation 1. The results of question 5.1 and 5.2 was further tested through question 5.3, which was asked at the end of the questionnaire.

Question 5.3 asked the viewers, through two different questions, which one animation they found the most realistic, and afterwards which one the most unrealistic. The responses were quite conclusive, with 62.28% saying that animation 1 is the most realistic, and in the next question 74.56% chose animation 3 to be the most unrealistic. It is however interesting, that the most unrealistic received 12.28 more percentage points. This indicates, that the highly physically unrealistic motion of animation 3, was easier to distinguish from the others, while the other two animations were less separated. 21.06% of the respondent were equally divided between animation 1 and 2, when asked to choose the most unrealistic version. The answers were however more oddly distributed, when asking participants to choose the most realistic, as only 7.89% said animation 3, while animation 2 scored 15.79 percentage points higher at 23.68%.

The intend of the question was to prove, that the scores of the previous two questions is a valid measure for the perceived realism, and to further validate the level of realism, when comparing animations. The distribution of responses does indeed match the rating, that the animations received in question 5.1 and 5.2, which also places animation 1 as being most realistic and animation 3 as the least realistic, with animation 2 scoring in between. When adding the two questions regarding realism, the cumulative score for

animation 1 is 4.55 points, animation 2 received a score of 4.10, and animation 3 only received a score of 3.15 out of a possible 7.
The reason for these results and why some animations scored lower, were investigated through question 5.4. This question asks the participants which specific aspects of the animations that seemed unrealistic to them, and the results show a number of recurring responses. Even though the participants were instructed that all the questions would be regarding the fluid, the answers mention nearly every possible aspect of the animation. I wish to address just the most recurring focal points, as they describe the weakest parts of the animation

The most addressed feature in animation 1 and 2, and third most in animation 3, was the fluid on the table. The main reasons, that are causing it to look unrealistic, is probably the low friction and smooth modelling used when simulating, as well as the missing wetmap and non-absorbing table. Especially the missing wetmap is a source for the decline in realism, as it causes the table to look dry, even though the wood should have absorbed some of the fluid.
The consistency of the fluid was also reported by several people as being the least realistic aspect of the animation. While some people directly used the word consistency, others described the fluid as looking too thick or sludgy. When comparing with the real-life referent, a few differences in consistency are apparent. The animated fluid has a high surface tension and do not form many drops, and when the liquid hits the table it clumps together, instead of being absorbed into the wood. The animation could also have benefitted from having a higher interaction resolution, to provide finer details when interacting with the geometry. As one participant mentioned; at one point part of the fluid seem to rest at the edge of the glass, when it should clearly fall off to one side.
These unrealistic aspects, reported by the test participants, do however not differ from one animation to the other, and while they are all a part of the overall perception of the realism, they are not related to the changing variable of the study. This means, that even though these features are a cause for a lower score regarding realism, the effect they have do not change between animations and as such should not be the cause of any differences in the results between conditions.

The participants did however also report aspects, that are connected to the body forces, as being unrealistic. Next after consistency of the fluid, the splash of the fluid was the most reported feature. When grouping the answers, it is necessary to try and decipher the intended meaning, as the respondents rarely use the technical terms. Several responses mention the force of the ice cubes, the splash of the liquid and how it sloshes around in the glass. These comments were divided into individual groups, to provide a more exact result, but it makes sense to combine them into one, which I will call *action/reaction*. The splash is the result of the ice cubes hitting the fluid, and in return the splash causes the liquid to slosh around in the glass. The Navier-Stokes equations state that mass times the acceleration of fluid is proportional to the forces acting on them. If this is applied to the animations, it says that the amount of force, that the ice cubes holds, is equal to the force being applied to the liquid, when they collide. Furthermore, the direction of the force on the ice cubes is opposite to the direction of the forces on the liquid. In short: the reaction of the fluid is proportional to the action of the ice cubes.

When combined, the comments regarding ice cubes, splash and sloshing, will be concerned with the action and reaction of these interconnected dynamics. This interaction will likely be one of the main focus areas for the participants (even if unconsciously) when judging realism. The only force, that the viewer sees being applied to the fluid, is the ice cubes falling into the glass, and as far as they are concerned, this is the only action that causes a reaction and sets the fluid in motion. This means, that many viewers will focus on this interaction when judging the level of realism. When asking participants to state the most unrealistic element, many where concerned with this interaction. 22.06% of the answers for animation 1 fit into the action/reaction group, while the number was 31.71% for animation 2 and 10.34% in animation 3. These numbers are consistent with expectations, when relating them to the forces being applied in animation 1 and 2, and the physical realism, that the impact of the ice cubes, holds.
Animation 1 does not have any additional forces applied when hitting the liquid, while animation 2 and 3 holds a lower interaction factor for the ice cubes and a crown daemon to create the splash. The number of people who mentioned these features could indicate that the significantly lower score that animation 2 received, when asked about physical realism, was due to this aspect. The other reason for pinpointing this action/reaction as the cause of the lower score, is simply that it is the only variable to change between animation 1 and 2, and as such a causal relationship, between this and the score, can be claimed.

Animation 3 received a significantly lower score than the others, both when asking about the look and about the physical realism. It was however not the ice cubes and splash, that caused the major drop in perceived realism, for animation 3. 45.98% of the answers reported the heart as being unrealistic, and another 21.84% mentioned the floating liquid. These two aspects are of course related and many of the answers treated them as one and the same. When the answers, mentioning the floating heart and the liquid, are combined, they provide 67.82% of responses and as such this was the only animation, where more than half of the participants gathered around one single aspect as being the most unrealistic. The floating liquid and heart are clearly violating physical realism and the results show that they are also the cause of the large dip in perceived realism.

The results confirm the hypothesis that adding forces, that are not using real-world physicality, will also lower the perceived realism. Animation 3 is of course an extreme case, but the viewers were also questioned about the less extreme use of forces in animation 2. Animation 3 showed significantly lower scores in both question 5.1 and 5.2 regarding realism. This was evidently caused by the floating liquid and heart, which are in direct violation of the gravitational force of real-life.
Reading through the comments, it would seem that some participants accept the floating liquid as being realistic, as it behaves in a way that could be realistic in a stylized reality. When asked to provide any further comments at the end of the questionnaire, one participant remarked: “I'm choosing the third video as the most unrealistic even though i rated it the most realistic previous [*sic*]. This is because before I took it as you were asking if the fluid movement looked realistic which it did, if it were to float in the air, while here you are asking if it looked realistic overall which it does not, because what happened is not realistic. I hope this makes sense :>”. This comment shows, that even when the fluid is in clear violation of real-life physics, it will still be judged by whether or not the motion is realistic. This might seem counterintuitive, but is likely because people are still able to judge the degree of realism in a setup that is inherently unrealistic. While the movement of the floating liquid behaves, as if it were inside a force field or invisible wind tunnel, the heart is much more restricted in its motion. And the more restricting physicality of the heart did seem to further remove it from reality, as it was clearly the most mentioned feature.
The setup of the simulation places the fluid inside of a heart-shaped object, which is invisible to the viewer and highly restricts the motion and shape of

the liquid. The heart was clearly perceived as the most unrealistic element, and one of the main reasons that animation scored a cumulative lower value of nearly 2 points, when asking to realism. This support the theory, that the more a force restricts the flow of the fluid, the lower the perceived realism will be.

## 6.3. ART DIRECTION AND MESSAGE

The results of the study confirmed hypothesis I and proved, that applying forces will likely lessen the level of perceived realism. The study was also used to provide new insight into the use of body forces as a means of art directing the fluid. To this regard, the participants of the user study were asked whether they thought each animation contained a message, and if so, what that message is. Of all the participants, 27.2% said that animation 1 contained a message and the result were almost the same for animation 2, with 26.3%. The number was much higher for animation 3, were 69.3% perceived the animation to contain a message.

Artistic choices, like the aesthetics of the splash, show intentions from the sender, that goes beyond just recreating reality, and as such some viewers could possibly perceive this as sending a message, however abstract it may be. The aesthetics of animation 2 did however not provide any increase in perceived meaning, when compared with the others. Feeling and meaning are related when reading a film and the assumption was that aesthetics of animation 2 might elicit an increase in the number of people who experienced a message in the animation. This was however not the case, which might be due to the animation not having a recognizable symbolic meaning, like animation 3 has. Another possibility is, that the aesthetics simply needed more work and a more pleasing motion, that spoke to the viewer. This is however speculations, which a future study could investigate further.

With each animation, the people who responded that it contained a message was further asked what that message is. The responses were quite similar for animation 1 and 2, and addresses themes like enjoy cola, commercial, great taste, summer and relaxation. The responses for animation 3 touched upon the same aspects, but the majority, 63.51%, converged on *love* as being the message. While this is the only animation, where more than half of the participants agreed on one single parameter, it too saw a substantial increase in the number of respondents, who experienced a message. This increase was evidently due to the liquid heart.

The heart shape was chosen because of its clear symbolism and connotations of love. Art direction can be a somewhat intangible matter, and the intention with the clear symbolism of the heart, was to see whether it was possible to create tangible results. The art direction of animation 3 is quite extensive, but it also creates results that clearly show that the message is being perceived by the viewer. These results show, that lesser degrees of art direction also have the potential to be understood by the viewer.
The art direction of animation 2 did however not provide any discernable changes to the result, when comparing with animation 1, but it might have, if instead of 'message' the viewers were asked about feelings or aesthetics. Of the people who saw animation 3 as the first video, 60.53% said it contained a message, while 73.68% of participants, who saw it as the second or third video, experienced a message. The first result demonstrates, that the video clearly does send a message on its own and the second (higher) percentage count shows, that the respondents are comparing animations, when forming their perception. Furthermore, when asking about the physical realism, the respondents who saw animation 3 as the first one, gave it almost a full point (0.9) higher on the 7-point scale.

## 6.4. FUTURE WORK

This study is interested in how fluid animations are perceived, in a format similar to what you see in film and TV. This entails shading, moving camera, complicated lighting and several other elements, that are external to the dimensions of interest. Additionally, several forces are being applied to the animation, and as such they become quite complex.
Future studies could test individual forces and how they affect the perceived realism. Finer increments in changes between animations, could provide tolerance threshold for each body force. To this regard, a user study with a staircase design would be useful, similar to the one used in the study on visual fidelity by O'Sullivan et al. (2003).
If this setup was used, many more animations would have to be created, with much smaller increments in the forces being applied. The participants would then report for each animation whether they perceived the physical

realism to be correct or not, and through that provide a threshold for when an applied force becomes unrealistic.

# 9. CONCLUSION

The hypotheses were, that art directing fluid animation, by applying body forces, will lessen the level of perceived realism, but that it can be useful in communicating a desired feeling and message to the viewer. The results showed, that an increase in body forces applied, will indeed result in a lower level of perceived realism. This holds true, when asking about the overall look of the animation, but becomes even more apparent, when asking to the fidelity of the fluid motion. The degree to which body forces will lower perceived realism, is connected to how constraining they are and how much they break with the laws of physics. To this regard, an understanding of the form and genre, to which the animation is intended, becomes crucial. The form of the film will decide the conventions and expectation of the animation and set the applicable laws of physics for this specific animation.

Whether an animation will successfully convey the feeling and message, intended by the FX TD, is difficult to determine conclusively, but the results of this study show, that it is possible to do so. The symbolism used to this regard was rather elaborate, but also afforded a strong response from the viewers. This indicates, that less constraining forms of art directions also has the possibility to transmit a message. Conveying a specific feeling is more difficult and this study was unsuccessful in communicating one to the participants of the user study. This was however not the main concern of the paper and further studies could prove otherwise.

Art direction is an integral part of film production, as realism is not the only target. The aesthetics of the animation is just as important and conveying the right message to the viewer. Realism and art directions may seem to be mutually exclusive, but understanding the effect of using forces, will help any FX TD to balance these two goals and achieve a desired level of both.

This paper has provided a vocabulary and tools that will help anyone working with the art direction of fluid animations. This is often a collaborative process, and as such a shared understanding and vocabulary is vital to arrive at the desired end result. Rather than providing clear cutoff threshold for each force, this paper has provided a method for understanding the level of realism that you can expect, when art directing fluid animation.

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# APPENDIX

## Figure A-1

Landing page javascript

```
<script type="text/javascript">

var urls = new Array();
urls[0] = "https://goo.gl/forms/uoNf3xYUUOcaAitg1";
urls[1] = "https://goo.gl/forms/NujbQA2Jf19gi6v13";
urls[2] = "https://goo.gl/forms/lsfMhSfFbxA5BK9I3";
urls[3] = "https://goo.gl/forms/VjfJiEOesQju1rn63";
urls[4] = "https://goo.gl/forms/MpbK7yBLmfdxtf7u2";
urls[5] = "https://goo.gl/forms/Pfs5XnpwdhInuSaW2";
urls[6] = "https://goo.gl/forms/uoNf3xYUUOcaAitg1";
urls[7] = "https://goo.gl/forms/NujbQA2Jf19gi6v13";
urls[8] = "https://goo.gl/forms/lsfMhSfFbxA5BK9I3";
urls[9] = "https://goo.gl/forms/VjfJiEOesQju1rn63";
urls[10] = "https://goo.gl/forms/MpbK7yBLmfdxtf7u2";
urls[11] = "https://goo.gl/forms/Pfs5XnpwdhInuSaW2";

var random = Math.floor(Math.random()*urls.length);

window.location = urls[random];

</script>
```

## Figure A-2

360° high dynamic range (HDR) image of a beach (Bloch 2011).

# Figure A-3

Questionnaire & the different orders

| Ordering of animations | | | | | |
|---|---|---|---|---|---|
| **Questionnaire A** | **Questionnaire B** | **Questionnaire C** | **Questionnaire D** | **Questionnaire E** | **Questionnaire F** |
| animation_1<br>animation_2<br>animation_3 | animation_1<br>animation_3<br>animation_2 | animation_2<br>animation_1<br>animation_3 | animation_2<br>animation_3<br>animation_1 | animation_3<br>animation_1<br>animation_2 | animation_3<br>animation_2<br>animation_1 |

## Questionnaire A

# Fluid Animation Questionnaire

Thank you very much for participating in this questionnaire and helping me with my master's thesis project. This project is concerned with the realism of computer simulated liquid.

By "realism" I mean that the liquid looks and behaves like it would in real life.

On the following pages you will be presented with videos (in slow motion) and afterwards asked to answer some questions regarding the video. Feel free to watch the video, as many times as you feel is needed, before answering the questions.

The same information is posted below in Danish.
----

Dansk:

Tusind tak for din deltagelse i denne undersøgelse og for at hjælpe mig med mit speciale. Dette projekt undersøger realisme i computersimuleret væske.

Med "realisme" menes der, at væsken ligner og agerer, som den ville i virkeligheden.

På de følgende sider vil du blive vist nogle videoer (i slow motion) og efterfølgende besvare en række spørgsmål vedrørende denne video. Du er velkommen til at se videoen, så mange gange som du synes, inden du besvarer spørgsmålene.

*Påkrævet

1. **What is your age? --- Hvad er din alder?** *

   ____________________

2. **What is your gender? --- Hvad er dit køn?** *
   *Markér kun ét felt.*
   - ◯ Female --- Kvinde
   - ◯ Male --- Mand
   - ◯ Prefer not to say --- Ønskes ikke oplyst

3. **Have you done professional work with Computer-generated images (CGI)? --- Har du arbejdet professionelt med computergenererede billeder (CGI)?** *
   *Markér kun ét felt.*
   - ◯ No --- Nej
   - ◯ Yes --- Ja

4. **On what kind of device are you currently viewing this questionnaire? --- På hvilken slags enhed besvarer du dette spørgeskema?** *
   *Markér kun ét felt.*
   - ◯ Laptop --- Bærbar computer
   - ◯ Desktop computer --- Stationær computer
   - ◯ Tablet
   - ◯ Smartphone
   - ◯ Andet: ____________________

5. **If you know, please provide information on the resolution and screen size of the device, or the name of the device/screen. --- Oplys venligt, hvis du kender den, din skærmstørrelse og opløsning, eller navnet på din skærm/enhed.**

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## RA

Please watch the video via the link below, in full screen, before answering any questions. Please return to the questionnaire afterwards, to answer the questions, which are all regarding the liquid in the glass.

Video link: https://youtu.be/V8tSm_BDOZQ

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Se venligst videoen på ovenstående link, i fuld skærm, inden du besvarer spørgsmålene. Bagefter bedes du vende tilbage til spørgeskemaet og besvare spørgsmålene, der allesammen vedrører væsken i glasset.

6. **Do you feel that the fluid looks realistic? --- Synes du at væsken ser realistisk ud?** *
   *Markér kun ét felt.*

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | |
|---|---|---|---|---|---|---|---|---|
| completely unrealistic --- Fuldstændig urealistisk | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ | completely realistic --- Fuldstændig realistisk |

7. **Do you perceive the movement of the fluid as being physically correct? --- Synes du at væskens bevægelse virker fysisk korrekt?** *
   *Markér kun ét felt.*

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | |
|---|---|---|---|---|---|---|---|---|
| Completely physically incorrect --- Fuldstændig fysisk ukorrekt | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ | Completely physically correct --- Fuldstændig fysisk korrekt |

8. **Did specific aspects of the visuals seem unrealistic to you? --- Var der specifikke elementer af det visuelle, du synes virkede urealistiske?**

______________________________

9. **Do you feel like the video contains a message? --- Synes du at videoen indeholder en besked?** *
   *Markér kun ét felt.*

   ◯ No --- Nej
   ◯ Yes --- Ja

10. **If yes, how would you describe this message? --- Hvis ja, hvordan vil du beskrive den besked?**

________________________________

## SA

Please watch the video via the link below, in full screen, before answering any questions. Please return to the questionnaire afterwards, to answer the questions, which are all regarding the liquid in the glass.

Video link: https://youtu.be/2Qde5Pts7Fc

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Se venligst videoen på ovenstående link, i fuld skærm, inden du besvarer spørgsmålene. Bagefter bedes du vende tilbage til spørgeskemaet og besvare spørgsmålene, der allesammen vedrører væsken i glasset.

11. **Do you feel that the fluid looks realistic? --- Synes du at væsken ser realistisk ud?** *
*Markér kun ét felt.*

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | |
|---|---|---|---|---|---|---|---|---|
| completely unrealistic --- Fuldstændig urealistisk | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ | completely realistic --- Fuldstændig realistisk |

12. **Do you perceive the movement of the fluid as being physically correct? --- Synes du at væskens bevægelse virker fysisk korrekt?** *
*Markér kun ét felt.*

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | |
|---|---|---|---|---|---|---|---|---|
| Completely physically incorrect --- Fuldstændig fysisk ukorrekt | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ | Completely physically correct --- Fuldstændig fysisk korrekt |

13. **Did specific aspects of the visuals seem unrealistic to you? --- Var der specifikke elementer af det visuelle, du synes virkede urealistiske?**

________________________________

14. **Do you feel like the video contains a message? --- Synes du at videoen indeholder en besked?** *
*Markér kun ét felt.*

◯ No --- Nej
◯ Yes --- Ja

15. **If yes, how would you describe this message? --- Hvis ja, hvordan vil du beskrive den besked?**

________________________________

## AA

Please watch the video via the link below, in full screen, before answering any questions. Please return to the questionnaire afterwards, to answer the questions, which are all regarding the liquid in the glass.

Video link: https://youtu.be/-vZcLEfTXCw

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Se venligst videoen på ovenstående link, i fuld skærm, inden du besvarer spørgsmålene. Bagefter bedes du vende tilbage til spørgeskemaet og besvare spørgsmålene, der allesammen vedrører væsken i glasset.

16. **Do you feel that the fluid looks realistic? --- Synes du at væsken ser realistisk ud?** *

    *Markér kun ét felt.*

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | |
|---|---|---|---|---|---|---|---|---|
| completely unrealistic --- Fuldstændig urealistisk | ⬭ | ⬭ | ⬭ | ⬭ | ⬭ | ⬭ | ⬭ | completely realistic --- Fuldstændig realistisk |

17. **Do you perceive the movement of the fluid as being physically correct? --- Synes du at væskens bevægelse virker fysisk korrekt?** *

    *Markér kun ét felt.*

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | |
|---|---|---|---|---|---|---|---|---|
| Completely physically incorrect --- Fuldstændig fysisk ukorrekt | ⬭ | ⬭ | ⬭ | ⬭ | ⬭ | ⬭ | ⬭ | Completely physically correct --- Fuldstændig fysisk korrekt |

18. **Did specific aspects of the visuals seem unrealistic to you? --- Var der specifikke elementer af det visuelle, du synes virkede urealistiske?**

    ______________________________

19. **Do you feel like the video contains a message? --- Synes du at videoen indeholder en besked?** *

    *Markér kun ét felt.*

    ⬭ No --- Nej

    ⬭ Yes --- Ja

20. **If yes, how would you describe this message? --- Hvis ja, hvordan vil du beskrive den besked?**

    ______________________________

21. **Of the three videos you have just seen, which one did you find the most realistic? --- Hvis du skal rangere de tre videoer du lige har set, hvilken synes du så virker mest realistisk?** *
*Markér kun ét felt.*

- The first video. --- Den første video.
- The second video. --- Den anden video.
- The third video. --- Den tredje video.
- Don't know. --- Ved ikke.

22. **Which video did you find the most unrealistic? --- Hvilken video synes du virkede mest urealistisk?** *
*Markér kun ét felt.*

- The first video. --- Den første video.
- The second video. --- Den anden video.
- The third video. --- Den tredje video.
- Don't know. --- Ved ikke.

23. **Any further comments? --- Har du yderligere kommentarer?**

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