Title	Flow Zone : inducing flow to improve subjective well-being by creating a cross-modal music creation experience in virtual reality
Sub Title	
Author	Person, Tanner(Minamizawa, Kota) 南澤, 孝太
Publisher	慶應義塾大学大学院メディアデザイン研究科
Publication year	2018
Jtitle	
JaLC DOI	
Abstract	
Notes	修士学位論文. 2018年度メディアデザイン学 第649号
Genre	Thesis or Dissertation
URL	https://koara.lib.keio.ac.jp/xoonips/modules/xoonips/detail.php?koara_id=KO40001001-00002018-0649

Master's Thesis

Academic Year 2018

Flow Zone: Inducing Flow to Improve Subjective Well-Being by Creating a Cross-Modal Music Creation Experience in Virtual Reality

Keio University Graduate School of Media Design

Tanner Person

A Master's Thesis
submitted to Keio University Graduate School of Media Design
in partial fulfillment of the requirements for the degree of
MASTER of Media Design

Tanner Person

Thesis Committee:

Associate Professor Kouta Minamizawa	(Supervisor)
Project Professor Tetsuya Mizuguchi	(Co-supervisor)
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Abstract of Master's Thesis of Academic Year 2018

Flow Zone: Inducing Flow to Improve Subjective Well-Being by Creating a Cross-Modal Music Creation Experience in Virtual Reality

Category: Design

Summary

Many people want to live a happy and fulfilling life, yet finding this positive sense of well-being is often quite a challenge. Flow is a wonderfully powerful experience that not only feels amazing in the moment, but actually improves a person's general sense of well-being as well. It seems like a great answer to this problem, but unfortunately the complex concoction of parameters necessary to enter flow prevent the experience from occurring regularly. Flow Zone lowers the barrier to entry with its sophisticated design tailored to maximize potential for flow. VR was used as the medium to create a highly immersive environment that simultaneously removes distractions and focuses the player's attention on the task at hand. The enhanced immersiveness of cross-modality combined with game design elements centered around creative expression through music creates a streamlined pathway to the flow state.

Keywords:

Flow, Well-Being, Virtual Reality, Transformative Technology, Positive Technology, Cross-Modality, Synesthesia, Music, Immersion

Keio University Graduate School of Media Design

Tanner Person

Acknowledgements

I am ever so grateful for my friend and colleague, Benjamin Outram, for his passion and energy in helping me develop Flow Zone. His like-minded dream of utilizing technology to transform the human experience offered me a wealth of inspiration and the motivation to give my all for this thesis. Not to mention his wizardly math skills played a large role in the physics elements of Flow Zone. I hope we can continue to take on this dream together.

I wish to thank my supervisor, Professor Kouta Minamizawa, for sharing his vast pools of knowledge and always encouraging me to push beyond the limits I set for myself. Throughout my time at KMD he often gave me advice that was precisely what I needed. Also, I want to thank him for the opportunities he gave to me to showcase my work where it was exposed to many diverse people, giving my project a rich user base to improve my experience design. Of course, I owe much of my success at KMD to him. Thanks for believing in me.

To my sub-supervisor, Professor Tetsuya Mizuguchi, I am grateful for the endless inspiration from his brilliant creations. It's a gift to have my future goals embodied in someone as real and friendly as him.

My research process was smooth and rewarding thanks to Roshan Peiris. His guidance and willingness to meet frequently played key roles in my success at KMD, and I cannot thank him enough for his support.

I want to thank MHD Yamen Saraiji for not only being a great friend, but also offering immense support and mentoring during my time at KMD. He was always someone I could turn to with any difficult questions or concerns from my work. Yamen also provided quality feedback throughout the course of my research and taught me a number of valuable skills when programming and integrating software with custom hardware. My experience in Japan would not have been the same without him.

I owe my thanks to Sergio Robles de Medina and Lane Rettig for helping Benjamin and I develop the first prototype, Virtual Poi, at Tokyo Junction. That experience was wonderful and offered a glimpse of what flow in VR could be. They

were both a source of great help and motivation.

Thanks Mihaly Csikszentmihalyi, for giving a name to a moment so beautiful and mysterious, allowing the people alive today the opportunity to find a direct path to happiness, well-being, and purpose.

And lastly, to Jamie Wheal and Steven Kotler, for reigniting my fire by reminding me of the power of flow.

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Chapter 1
Introduction

1.1 The Significance of Flow

It was the final penalty shot of the game. The score was 4-3, and this shot was the match point. If the keeper could block this shot, his team would make it into the playoffs. All eyes were on the kicker, but the keeper only had eyes for the ball. Nothing else in the world mattered besides where this single object moved. He was in a state of extreme focus, no thoughts entering his mind to distract him from the only thing that held any importance to him in that moment. As the ball moved, the keeper, as if automatically, lunged to the left with arms outstretched as far as they possibly could. For that split second, time seemed to stop. The moment, infinite. As the crowd screamed, the keeper was engulfed by the arms of his teammates, their voices seemingly far off in the distance. Beside himself, the keeper still hadn't fully realized what had happened because he was so enraptured by the profound save he'd just made and the joy he was overwhelmed by. He would remember that moment for the rest of his life.

This is one of the most poignant experiences I have had in *flow*, an optimal state of consciousness often characterizing the moments that enter the highlight reel of one's life, the moments people are both performing their best and feeling their best. In these moments, whatever task is at hand becomes the sole focus of attention, and everything else seems to disappear. Actions merge with awareness, becoming effortless and natural. Time warps so much it can even appear to stop. Not to mention, it feels amazing, too. The joy experienced from flow not only produces happiness in the short term but also leads to a heightened sense of life satisfaction in the long-term. It singlehandedly increases someone's present and future well-being at the same time.

Flow is available to anyone, anywhere, as long as the experience satisfies some certain conditions. It can happen while reading a novel, taking the kids on a Sunday afternoon bike ride, surfing a stellar wave, programming an A.I. software,

or painting an absolute smorgasbord of emotions into existence.

1.2 The Challenges of Entering Flow

If it is such an appealing state to be in, why isn't everyone in it all the time? Well, that's where the problem lies. Flow is highly elusive, and usually takes a considerable amount of effort to achieve. For instance, one challenge is that it often requires extensive training in a particular skill in order to reach the level required for flow. Another reason is that many of the activities that more easily get someone into flow require a high level of risk, where the person may become seriously injured. For example, playing in a team sport such as soccer or an extreme sport such as rock climbing or sky diving. The main challenges to entering flow with any task are maintaining a high level of concentration and hitting that sweet spot where challenges are present but matched with the skill to overcome those challenges.

So, is there a way to make flow more accessible without so much initial effort? This thesis explores this question and proposes one viable medium: virtual reality (VR).

Figure 1.1: VR's potential for flow [1]

1 Figure 1.1 credit: `https://www.vrs.org.uk/images/virtual-reality-immersion-1.jpg`

1.3 Virtual Reality as a Catalyst for Flow

There are several reasons virtual reality is especially well equipped to induce flow. This is because of its inherent characteristics as well as the potential it offers for experience designers.

VR is an exceptional medium for video games, and video games are ideal systems for flow as will be explained later. What sets VR apart from other video game mediums is its unique elements that both induce and maintain flow. It's immersive nature captures player attention, keeping them concentrated on the virtual environment and activity they are experiencing. It also removes potential distractions from the real world by blocking out both audio and visual sensory input. In essence it is an ideal of an ideal, the pinnacle of video game flow potential. VR brings many elements of flow together into one, cohesive form.

1.4 Proposal

In effect, virtual reality catalyzes the flow state, and flow improves well-being. This thesis explores elements of a VR experience that contribute to flow, then provides a possible solution that maximizes the potential of those elements. The outcome of this thesis is Flow Zone, a cross-modal music creation VR experience. The cross-modal element provides a highly immersive sensorial environment where audio, visuals, and haptics are synchronized. Music multiplies this effect by creating order out of the cross-modal sensations. And lastly, creation gives players the interactivity necessary for a flow state, where engagement with a task is vital. All of these elements together produce a situation optimized to induce flow.

To sum it up, this thesis provides the following contributions:

- Identifying elements that work cohesively to induce flow in virtual reality
- Utilizing these elements to create Flow Zone, a solution that optimizes virtual reality's potential for flow

1.5 Thesis Structure

This thesis consists of 5 chapters. Chapter 1 presents the background that describes the need for this thesis. Following that is chapter 2, which goes over the

relevant research, concepts, and applications. Chapter 3 outlines the process designing the concept that is utilized by the system developed in chapter 4. Chapter 5 provides a summary of this work and offers some conclusions.

Chapter 2
Literature Review

2.1 Well-Being

There is not a clear consensus on the definition of well-being.[1] The meaning has been used synonymously with other terms like happiness, self-actualization, contentment, adjustment, economic prosperity, and quality of life.[2] However, the concept of well-being can roughly refer to optimal psychological functioning and experience.[3] For this thesis, the focus is on changing the user's subjective sense of well-being. In other words, how does a person evaluate their perceived sense of well-being regardless of the user's objective condition in life?

Currently, well-being is categorized into two distinct perspectives, as explained in *On Happiness and Human Potentials: A Review of Research on Hedonic and Eudaimonic Well-Being.*[5] The first perspective, hedonic well-being, refers to well-being that derives from pleasure or happiness. The typical way to determine well-being in this line of research is based on the degree of someone's "subjective well-being" (SWB), which is measured as a combination of life satisfaction, the presence of positive affect, and the absence of negative affect. SWB is often used synonymously with happiness.

The second perspective, eudaimonic well-being, states that fulfilling one's purpose or experiencing growth is the true origin of well-being. This way of thinking

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1 (Snyder et al. 2010)

2 (Hefferon and Boniwell 2011) *Positive psychology: Theory, research and applications* (p. 45)

3 (Ryan and Deci 2001)

4 From the *Wellbeing Language & Definitions Guide*: `https://education.unimelb.edu.au/__data/assets/pdf_file/0006/2483691/language-and-definitions-guide-web.pdf`

5 (Ryan and Deci 2001)

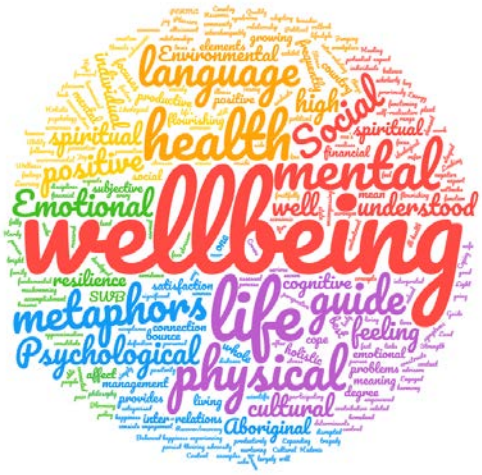

Figure 2.1: List of words associated with well-being [4]

falls in line with Maslow's concept of *self-actualization*[6], which is the experience of realizing one's fullest potential. In this case, one does not always have to experience happiness in order to have a sense of well-being, as long as what one is doing contributes to the development of the self.

In the context of this thesis, both approaches to well-being are considered. Auspiciously, the flow state contributes to an increase in both hedonic and eudaimonic well-being, as Monoeta[7] beautifully articulates:

> Flow theory constitutes a synthesis of hedonic and eudaimonic approaches to subjective well-being. Consistent with the hedonic perspective, flow theory states that flow has a direct impact on subjective well-being by fostering the experience of happiness in the here and now. Consistent with the eudainomic perspective, flow theory states that flow has an equally important indirect effect on subjective well-being by fostering the motivation to face and master increasingly difficult tasks, thus promoting lifelong organismic growth. In particular, flow theory states that the frequency and intensity of flow in everyday life

6 (Maslow 1943)

7 Moneta, Giovanni B (2004, p. 116) (Moneta 2004)

> pinpoint the extent to which a person achieves sustained happiness through deliberate striving, and ultimately fulfills his or her growth potential.

Because of this, the general term "well-being" will used in this thesis to refer to both hedonic and eudaimonic aspects.

2.2 The Flow State

What is Flow?

Defining flow in a succinct manner is difficult considering the variety of phenomenological effects that come as a result of the state. For this reason, researchers often define flow as it relates to their study, highlighting its effects on things such as enjoyment[8], performance[9], or engagement[10]. Yet, in order to effectively define the concept of flow, it's important to elaborate on all of its nine major qualities, as articulated in Csikszentmihalyi's landmark book, *Flow: The Psychology of Optimal Performance*[11]:

1. A Challenge-Skill Balance
2. Clear Goals
3. Immediate Feedback
4. Concentration on the Task at Hand
5. The Merging of Action and Awareness
6. The Loss of Self-Consciousness
7. A Sense of Control

8 (Cheron 2016)

9 Kotler, Steven (2014, p. viii) *The Rise of Superman: Decoding the Science of Ultimate Human Performance* (Kotler 2014)

10 (Bian et al. 2016)

11 Csikszentmihalyi, Mihaly (1990, p. 49) *Flow: The Psychology of Optimal Performance* (Csikszentmihalyi 1990)

8. The Transformation of Time

9. The Autotelic Experience

Qualities 1-3 refer to prerequisites necessary to enter flow. The latter six qualities (4-9) refer to the phenomenological effects of being in flow.[12]

Csikszentmihalyi concludes that the reason flow is so effective is in how it creates more *negentropy* in human consciousness, giving it more order.

Qualities of Flow

A Challenge-Skill Balance

This quality refers to a person's ability to meet the requirements of a given activity, be it physical, mental, etc., while simultaneously being challenged sufficiently enough that they refrain from becoming bored of said activity. As shown in Figure 2.2, flow is found in a situation where a high amount of challenge meets a high level of skill, which Csikszentmihalyi calls the *flow channel*. "Enjoyment," states Csikszentmihalyi, "appears at the boundary between boredom and anxiety, when the challenges are just balanced with the person' s capacity to act." [13] If the activity deviates from this golden ratio, one will become either increasingly anxious or bored depending on which axis has become weaker.

Clear Goals

An activity suitable for flow requires clear goals that give one a sense of how close they are to completion. This goal can be accomplished quickly or take a long time to finish. What's important is that the person understands what these goals are. A good way to create clearer goals is by breaking down larger goals into smaller, more digestible chunks. This way it is possible to reevaluate our place on the way to completion more frequently and accurately.

Immediate Feedback

Intimately intertwined with clear goals, this quality is what gives one the ability to evaluate their progress on achieving one's set goal. Without immediate feedback,

12 (Nakamura and Csikszentmihalyi 2009)

13 Csikszentmihalyi, Mihaly (1990, p. 52) (Csikszentmihalyi 1990)

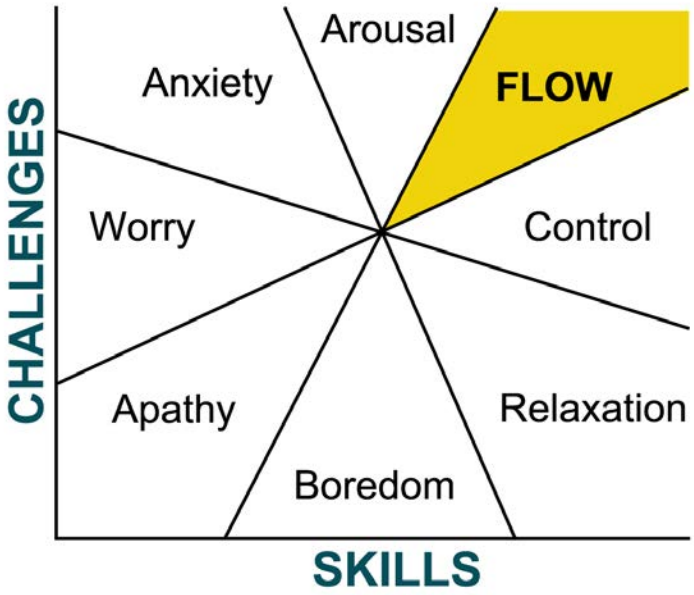

Figure 2.2: The challenge/skill ratio chart from (Csikszentmihalyi 1997)

it's impossible to quickly evaluate how one is doing on the way to achieving whatever goal one has set out to achieve. The keyword here is *immediate*, as the feedback must be instant and unambiguous in order to keep the mind in the present moment. Otherwise, the mind will end up asking itself, "Is this correct?" or, "Is there more I should do?", which necessitates leaving the present moment in order to ponder the past or future. Once we leave the present moment, flow is lost.

Concentration on the Task at Hand

In the flow state, a person's attention is fully given to the task occurring in the present moment. No resources are reserved for considerations of sensory data from other aspects of the environment or thoughts regarding the past or future. Because of this, additional energy can be allocated to enhance focus and attention, increasing one's ability to intake more information about the present.[14]

In order to attain this high level of concentration, people often need to go

14 (Slagter et al. 2007)

somewhere that removes them from the distractions of their everyday life.[15] In effect, this allows their minds to more easily forget about anything unrelated to the present environment and temporarily enter into a separate reality. This is a common attitude in martial arts dojos, where it's expected for everyone to leave their lives at the door in order to focus solely on what's experienced on the mat.[16]

It's important to remove as many distractions as possible, because even the slightest distraction can take us completely out of flow.[17]

The Merging of Action and Awareness

For the duration of flow, a person's awareness is entirely absorbed by the given activity. This can make it feel as if the activity becomes effortless, as if happening on its own. As Csikszentmihalyi puts it, "people become so involved in what they are doing that the activity becomes spontaneous, almost automatic."[18] This is because all of their attention is focused on the activity, leaving the mind no leftover mental energy to question itself. The only thing that exists in flow is the action taking place in the ever-present moment.

Loss of Self-Consciousness

Something particularly interesting happens phenomenologically upon entering flow as a byproduct of a person's awareness merging with their actions. Similar to how thoughts on the past and future disappear, when all of a person's attention is focused on the task at hand there is not even enough reserved energy to maintain awareness of the self. Once this takes effect, people stop perceiving themselves as separate from the action taking place. "What slips below the threshold of awareness is the concept of self, the information we use to represent to ourselves who we are."[19] In effect, this frees them from everything holding them

15 Csikszentmihalyi, Mihaly (1990, p. 58-59) (Csikszentmihalyi 1990)

16 "Leave your life at the door" was an explicit instruction often given by Linda Holiday Sensei and other instructors during my time training at the Aikido of Santa Cruz Dojo. Another reference to this mentality can be found in Csikszentmihalyi's *Flow* (1990, p. 59) (Csikszentmihalyi 1990) from a dancer interviewee.

17 Csikszentmihalyi, Mihaly (1990, p. 554) (Csikszentmihalyi 1990)

18 Csikszentmihalyi, Mihaly (1990, p. 53) (Csikszentmihalyi 1990)

19 Csikszentmihalyi, Mihaly (1990, p. 64) (Csikszentmihalyi 1990)

back as a person. They are completely uninhibited to the experience. Sometimes their sense of self even expands into the world around them, where they can feel they *are* the environment. If a person enters flow while rock-climbing for instance, they can have the experience of feeling like the rocks are somehow part of their sense of self, which is a type of transpersonal experience.[20]

A Sense of Control

Control is important to the flow equation as it reassures the person that they are in charge of their experience. The current situation is well understood and all concentration can be reserved for the present task. Risks or unforeseen circumstances are mitigated, leaving the person feeling secure and confident. Csikszentmihalyi clarifies that what people enjoy here is not necessarily always being in control, but rather the ability to exercise control over a situation. In other words, when something unfavorable happens, that person is able to take action to ensure they can correct the situation or avoid negative repercussions, and thereby regain control once again.

The Transformation of Time

When in a flow state, time seems to go at a different speed. This can be perceived as a slowing down of time, a speeding up of time, or as time standing still. This is sometimes called "the deep now"[21], a state when one can' t separate past, present, and future, and instead one experiences an elongated present.

The Autotelic Experience

The final quality of flow is also what Csikszentmihalyi claims is the most important. The autotelic (auto = self, telos = goal) experience is an experience that is intrinsically rewarding, an end in itself. The reason a person in flow is paying attention to the task at hand is for the sake of the experience itself, not because of the outcomes that result from the activity.

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20 (Walsh and Vaughan 1993)

21 Kotler, Steven and Wheal, Jamie (2017, p. 40) *Stealing fire: How Silicon Valley, the Navy SEALs, and maverick scientists are revolutionizing the way we live and work* (Kotler and Wheal 2017)

Flow Triggers

In *The Rise of Superman*[22], Kotler describes *flow triggers*, conditions of an activity that speed up entrance into the flow state. These derive from his years of experience researching extreme athletes, from people reaching the heavens with sky diving to those inclined to explore the depths of the ocean in the extremely dangerous form of free diving. Kotler discovered four categories of triggers that push people quickly into flow:

1. Internal Triggers: psychological strategies that drive people into the now
2. External Triggers: qualities of the environment that drive people deeper into the zone
3. Social Triggers: ways to alter social conditions to produce group flow
4. Creativity: creativity triggers flow, then flow enhances creativity

Because social triggers are beyond the scope of this thesis, only external, internal, and creative triggers will be discussed.

Internal Triggers

The internal category consists of four triggers. Three are direct references to Csikszentmihalyi: *a challenge-skill ratio*, *clear goals*, and *immediate feedback*. The last one is *intensely focused attention*, which is just another way of saying "concentration on the task at hand".

External Triggers

External triggers deviate from the theoretical framework laid out by Csikszentmihalyi. However, they help clarify the type of environments most conducive to flow and are especially useful for an experience designer. Environments with *high consequences* (i.e., risks, dangers) quickly induce flow as they force users to focus in order to not be injured. The second trigger is a *rich environment*, which are situations with a "combination platter of novelty, unpredictability, and complexity–three elements that catch and hold our attention much like risk."[23]

22 (Kotler 2014)

23 Kotler (2014, ch. 6) (Kotler 2014)

The last trigger in this category is *deep embodiment*, which refers to any situation where a person experiences a high amount of bodily awareness. This could come in the shape of a multi-sensory experience, where people are exposed to a high degree of combined audio, visual, haptic, and other types of sensory input. This trigger is effective because it overloads someone's ability to process the sensory input consciously. Instead, they must rely on their implicit (i.e., subconscious) system, which promotes action instead of thinking.[24] This is similar to the effects described in Csikszentmihalyi's *concentration on the task at hand*, in that mental energy is diverted away from thinking and instead directed towards subconscious processing.

Creativity

The last trigger is in a category all to itself. *Creativity* can be defined as "the process of developing original ideas that have value" and is an especially potent flow trigger.[25] Kotler explains that this happens via a combination of risk-taking and pattern recognition. Both produce dopamine in the brain, which helps people focus. "Once you' ve thrown out the rule book," explains psychologist Ned Hallowell, "and begun making creative decisions, the risk involved tightens focus and triggers a neurobiological cascade–it sweeps you right into flow." [26]

The Effects of Flow on Well-Being

Arguably, the most important outcome of flow is how it improves our sense of well-being. Indeed, the pursuit of happiness is what initially led Csikszentmihalyi to its discovery (or "rediscovery" as he would put it as flow has been experienced since the beginning of humankind).[27] Flow mainly does this by giving order to our consciousness.[28] "This simple truth–that the control of consciousness determines the quality of life–has been known for a long time; in fact, for as long as human

24 Kotler (2014, ch. 6) (Kotler 2014)

25 (Kotler 2014)

26 Interview with Ned Hallowell. Kotler (2014, ch. 9) (Kotler 2014)

27 Csikszentmihalyi, Mihaly (1990, p. 3) (Csikszentmihalyi 1990)

28 Csikszentmihalyi, Mihaly (1990, p. 22) (Csikszentmihalyi 1990)

records exist."[29]

Fritz found that for music experiences, flow impacted both emotional and cognitive aspects of well-being, but with a much larger impact on the emotional aspects.[30]

Flow can improve well-being even after the experience is over.[31] This is due to its eudaimonic aspects, which give people a sense of personal growth and a sense of purpose.[32]

The five key neurotransmitters involved during flow–dopamine, norepinephrine, endorphins, anandamide, and serotonin–help explain why people feel such a great sense of well-being during and afterwards (see Figure 2.3).[33] These release chemicals that produce pleasurable sensations and enhance one's ability to maintain flow.

Measuring Flow

Given the powerful effects flow has in various fields, much attention has been given to effectively measure the flow state. There are five major methods used: interviews, questionnaires, the Experience Sampling Method (ESM), objective measurements, and laboratory manipulations.[34]

Interview

Csikszentmihalyi used interviews extensively while originally developing the concept of flow.[35] Interviews give researchers a deep, rich understanding of the contents of flow and are still used today for exploratory research[36] and studies aiming

29 Csikszentmihalyi, Mihaly (1990, p. 20) (Csikszentmihalyi 1990)

30 (Fritz and Avsec 2007)

31 (Hefferon and Boniwell 2011)

32 (Ryan and Deci 2000)

33 Kotler (2014, ch. 4) (Kotler 2014)

34 (Nakamura and Csikszentmihalyi 2009)

35 (Csikszentmihalyi 1990)

36 (Reed et al. 1996)

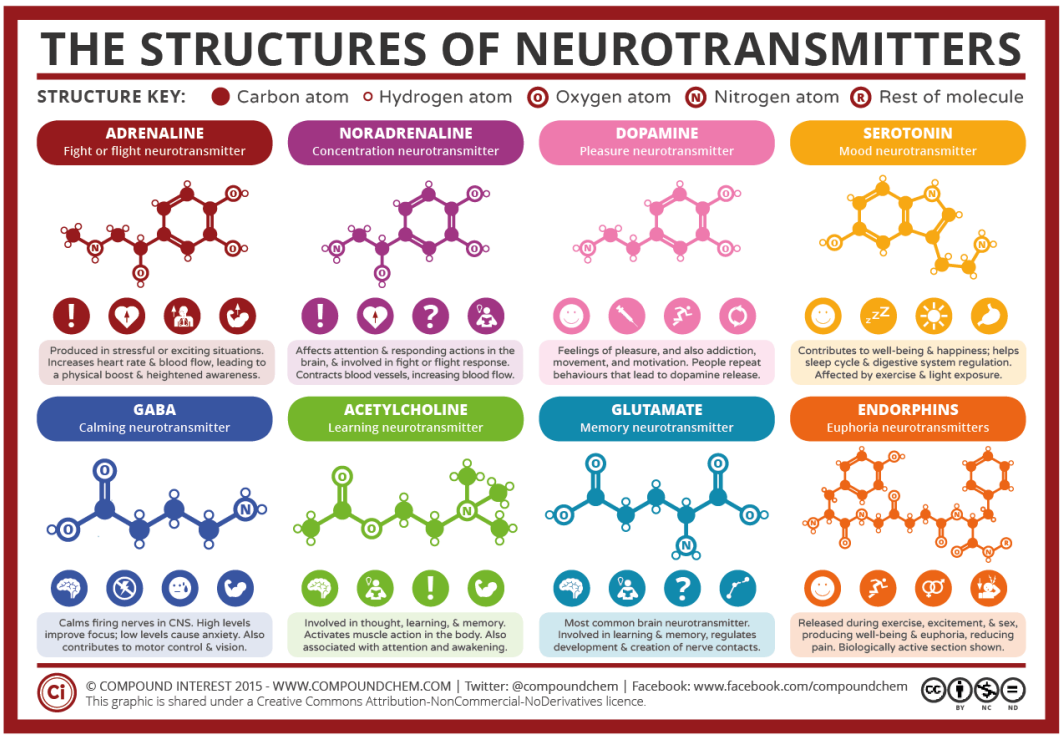

Figure 2.3: A partial list of neurotransmitters and their functions

to more fully integrate flow into the broader field of human science.[37]

Questionnaire

Questionnaires are used when the goal is to evaluate when someone is in flow or to measure differences in flow between people and contexts. It is necessarily done in a self-reflective manner where people consider either a past or future event.

In the last couple decades, the most widely used set of flow questionnaires have been those created by Jackson and colleagues.[38] These have been repeatedly shown to accurately and reliably detect the flow experience across all of its nine dimensions.[39] The Dispositional Flow Scale (DFS) determines someone's flow propensity in a given activity, that is how likely someone is to enter flow for that type of activity in general. The Flow State Scale (FSS), on the other hand, evaluates the level of flow someone had in an activity that was just recently completed. Both scales have a long (36-point-scale) and short (9-point-scale) version best used in various situations. The long version is useful in distinguishing the strength of each quality of flow (e.g., challenge-skill balance was high but sense of control was low), whereas the short version excels when needing to determine an overall level of flow (e.g., the participant experienced a high level of flow) or when time is of the essence. These scales were later revised to DFS-2 and FFS-2 respectively to better assess several dimensions of flow[40], and have also been repeatedly verified.[41]

Experience Sampling Method

This is the key method utilized by Csikszentmihalyi to determine when people most often experience flow in their daily lives.[42] Participants are given paging devices that go off at certain intervals, each time signaling the participants to fill out a questionnaire to determine their current psychological state in that moment

37 (Jackson 1995); (Neumann 2006); (Perry 1999)

38 See Mind Garden for up-to-date information: https://www.mindgarden.com/100-flow-scales

39 (Jackson and Marsh 1996); (Engeser 2012); (Schüler and Engeser 2009)

40 (Jackson and Eklund 2002)

41 (Jackson et al. 2008); (Johnson et al. 2014)

42 (Csikszentmihalyi 1990)

(see Figure 2.4). ESM has been used in many situations over the course of many years to reliably indicate the situations individuals most often experience flow.[43]

Figure 2.4: An example of an experience sampling application[44]

Objective Measurement

While the theoretical foundations for flow have been widely verified, empirically testing flow has deemed challenging. Objectively measuring flow is of utmost importance though as other methods such as interviews and questionnaires are retrospective in nature, while flow is quintessentially experienced in the present moment. The main solution for this is to use physiological sensors to detect for flow without disrupting the person, which is necessary because any distractions take one out of flow. Fortunately, there has been a resurgence of interest in this measurement type in recent years, as new methods of quantitatively measuring brain activity and bodily functions have opened the doors for many new possibil-

43 (Csikszentmihalyi and Rathunde 1993); (Hektner et al. 2007); (Nakamura and Csikszentmihalyi 2014); (Schmidt et al. 2014)

44 Figure 2.4 credit: `https://cdn-images-1.medium.com/max/1600/1*7PLKTIz5bu5ywW2HUdDxrg.png`

ities to measure flow objectively.[45]

Research into the physiological mechanisms for flow have found an association with cortex activity, cortisol activity, autonomic nervous system (ANS) activity, dopamine, and facial muscle activity.[46] These measurements can detect flow characteristics related to arousal, positive valence, mental effort, and attention.[47]

One of the common goals in these studies was to develop real-time measurements of flow in order to create adaptive systems that respond to a users current flow levels. To this end, Bian consolidated the various physiological measurements of flow into a physiological evaluation model (see Figure 2.5).[48]. They left out measurements of dopamine and cortisol activity from their model because currently there are no methods to obtain that data in real-time.

Laboratory Manipulation

This is the other main method to empirically test for flow in which researchers create highly controlled experimental setups to compare levels of flow in a given set of experimental conditions. These conditions usually involve adjusting various variables of flow such as levels of challenge and skill in an activity (e.g., online games).[49] Researches then analyze the differences using participant questionnaire responses or physiological data in order to examine which experimental conditions were most flow inducing.

For example, to study flow and immersion, Nacke[50] conducted an experiment using a within-group design in which participants played three different modified versions of the classic first-person shooter, Half-Life 2[51], where each mod was designed to elicit a type of game experience: boredom, immersion, or flow. Participants' physiological data was recorded during gameplay using electroencephalography, electrocardiography, electromyography, galvanic skin response and eye

45 (Engeser 2012)

46 (Goleman 2006); (Marr 2001); (Dietrich 2003); (Rheinberg 2008); (Peifer et al. 2014)

47 (Bian et al. 2016)

48 (Bian et al. 2016)

49 (Pearce et al. 2005)

50 (Nacke and Lindley 2008)

51 (Corporation 2004)

Table 1 Physiological evaluation model for flow experience

First-level physiological indicators	Second-level physiological indicators	Functions
Electromyography (EMG)	Corrugator supercilii (CS)	Increased by negative affect and inhibited by positive affect; indicator for mental effort
	Zygomaticus major (ZM)	Increased by positive affect and inhibited by negative affect
	Orbicularis oculi (OO)	Increased by positive affect and inhibited by negative affect
Cardiovascular activity	Heart rate (HR)	Increased by sympathetic nervous system activity and decreased by parasympathetic nervous system activity
	Heart period (HP)	Inverse of HR
	Interbeat interval (IBI)	Decreased by sympathetic nervous system activity
	Heart rate variability (HRV)	An indicator for mental effort
	Low-frequency band (LF)	Indicator for sympathetic activity; a marker for physiological arousal
	High-frequency band (HF)	Indicator for parasympathetic activity
	LF/HF ratio (LF/HF)	Reflecting sympathetic modulation; a marker for physiological arousal
Electrodermal activity (EDA)	Skin conductance (SC)	Increased by sympathetic activation; increased by stressful situation
	Skin resistance (SR)	Inverse of skin conductance
	Tonic EDA	Indicator for vigilance, sustained attention, and heightened arousal over time
	Phasic EDA	Event-related skin conductance response
Respiratory activity	Respiratory rate (RR)	A marker for physiological arousal
	Respiratory depth (RD)	Indicator for parasympathetic activity
Electroencephalogram (EEG)	Alpha	Indicator of relaxed, but not drowsy, tranquil, conscious mental state
	Low beta	Indicator of relaxed yet focused, integrated mental state
	Mid-beta	Indicator of thinking, aware of self and surroundings

Figure 2.5: Physiological evaluation model for flow experiences from (Bian et al. 2016)

tracking equipment. After each condition finished, participants were asked to fill out a Game Experience Questionnaire.[52] This way they were able to compare both physiological data and questionnaire data together.

2.3 Positive Technology

Recently, there has been an influx of interest in designing technology to increase well-being. In fact, it's become so popular that it spawned the Transformative Technology Conference[53] and Consciousness Hacking[54], an international movement bringing these creators together.

In the field of psychology, cyberpsychology was developed as a means to study the effects information technology has on humans. From that field, the classification of "Positive Technology" was born, which refers to technology that improves personal development and well-being.[55] Riva and colleagues[56] define this approach to technology as "the scientific and applied approach for the use of technology in improving the quality of our personal experience through its structuring, augmentation and/or replacement - as a way for improving and sustaining personal change." In the proposed framework, positive technologies are classified according to their effects on these aspects of personal experience:[57]

1. Hedonic: technologies used to induce positive and pleasant experiences.
2. Eudaimonic: technologies used to support individuals in reaching engaging and self-actualizing experiences.
3. Social/Interpersonal: technologies used to support and improve social integration and/or connectedness between individuals, groups, and organizations.

52 (Brockmyer et al. 2009)

53 Transformative Technology Conference: `http://www.ttconf.org/`

54 Consciousness Hacking: `http://www.cohack.life/`

55 (RIVA1-a 2012); (Botella et al. 2012); (Riva et al. 2012); (Wiederhold and Riva 2012)

56 (Riva et al. 2016)

57 (Botella et al. 2012)

Unsurprisingly, this characterization closely resembles the standard concepts of well-being as discussed earlier in this chapter along with the addition of a third element to capture the social dimensions of well-being.[58] As the social aspects of well-being are beyond the scope of this thesis, only positive technologies that focus on hednoic and eudaimonic well-being will be discussed in this section.

Hacking Well-Being

In both academia and industry, a variety of technologies have been developed in pursuit of improving well-being. Look no further than the TransTech 200[59] to see that a massive amount of organizations are getting involved (see Figure 2.6). Below are some areas that are being explored.

Figure 2.6: The TransTech 2017 Market Map

58 (Keyes and Lopez 2002); (Seligman 2004)

59 TransTech 200: `http://transtech200.com/`

Mindfulness

Mindfulness has been a key development in the positive technology space, as it has been shown to powerfully improve well-being along with a number of other benefits.[60] The lack of movement while practicing mindfulness makes it extremely viable for capturing data using a variety of techniques including electroencephalography (EEG), respiration, and functional magnetic resonance imaging (fMRI).[61] Many commercial applications have been developed, especially in the mobile application market[62] with the advent of accessible wearable technology that measures physiological data like the Apple Watch[63] and Muse headband.[64]

Virtual Reality

Virtual reality has been used in a number of ways to improve well-being. It's been shown to induce awe in users[65], which has considerable potential to transform our physiological and psychological well-being.[66] VR increases someone's willingness to train in mindfulness,[67] and also expedites the mindfulness skill training process.[68] Some commercial applications based on such research have been developed such as Guided Meditation VR,[69] and Flow for Breath[70]. There is even an application designed to induce a trance state.[71] VR has also been used to induce flow, which will be discussed in a later section.

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60 (Davis and Hayes 2011); (Heeren and Philippot 2011); (Shapiro and Walsh 2003); (Zeidan et al. 2010)

61 (Ahani et al. 2013); (Hagerty et al. 2013)

62 (Plaza et al. 2013)

63 Apple Watch: `https://www.apple.com/lae/watch/`

64 Muse headband: `http://www.choosemuse.com/`

65 (Chirico et al. 2017)

66 (Shiota et al. 2007); (Schneider 2009); (Stellar et al. 2015)

67 (Flores et al. 2018); (Gomez et al. 2017); (Navarro-Haro et al. 2017)

68 (Choo and May 2014); (Gonçalves et al. 2012); (Perhakaran et al. 2016)

69 Guided Meditation VR: `https://guidedmeditationvr.com/`

70 Flow for Breath: `http://www.corereboot.com/`

71 VR trance game - Soundself: `https://soundselfgame.com/`

Looking forward, several researchers[72] have identified four areas of technology most likely to improve well-being in the future: machine learning, psychopharmacology, non-invasive brain stimulation, and virtual reality.

Flow Technology

Flow has been studied quite extensively in the technology sector in recent decades. Below are some areas where flow has been both studied and applied that are relevant to the topic of this thesis.

Flow in Video Games

Video games are an ideal medium to induce flow because they possess characteristics that help create and maintain flow, such as the ability to create a challenge-skill balance, clear goals, and immediate feedback.[73] Players can become so involved in a game that nothing else matters, and other thoughts or concerns are forgotten[74] Players of video games often report losing track of time as they play.[75] Their defining characteristic of interactivity also gives players a sense of control over their environment.[76] Studies have also shown that playfulness can help activate flow[77], and video games are generally based around play.[78]

Immersion is also a common effect experienced from playing video games[79], which has been closely linked to flow.[80]

72 (Harari 2016); (Yaden et al. 2018)

73 (Sherry 2004)

74 (Sekhavat and Zarei 2018)

75 (Procci et al. 2012)

76 (Rigby and Ryan 2011)

77 (Chou and Ting 2003)

78 (Crawford et al. 2007)

79 (Calleja 2011); (Hjorth 2011); (Majorek and Du Vall 2016); (Rigby and Ryan 2011)

80 (Limperos et al. 2011)

Flow in Virtual Reality

Studies have explored the relationship between flow and VR in recent years as affordable, high quality virtual reality devices have become available. Flow is widely used to study user experience (UX) in VR.[81] It's considered an important goal in VR system design.[82]

While flow has been found repeatedly in VR, it does not necessarily improve performance. Bian[83] found that this may be due to an incongruence between virtual artifacts and their use. They designed an VR tennis game to test this and found that when objects in VR are matched with the specified task, performance finally improved. This is important to consider when designing VR experiences where training or improved performance are desired outcomes.

I'd like to highlight several commercial VR applications designed to induce flow (see Figure 2.7). These all capitalize on music and art in their attempts to induce flow. MicrodoseVR[84] combines the power of creativity, art, and music to provide a compelling flow experience. Beat Saber[85] uses the tried-and-true music rhythm formula similar to the likes of RockBand[86], and clearly produces impressive results as shown in the raving reviews found all over the internet. Tetris Effect VR[87] also maximizes the potential of cross-modality and engaging gameplay to induce flow. These all use methods similar to the application developed for this thesis.

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81 (Bian et al. 2016); (Gai et al. 2017); (Harmat et al. 2015); (Sun et al. 2017); (Tozman et al. 2015)

82 (Berta et al. 2013)

83 (Bian et al. 2018)

84 Microdose VR: `https://microdosevr.com/`

85 Beat Saber: `http://www.beatsaber.com/`

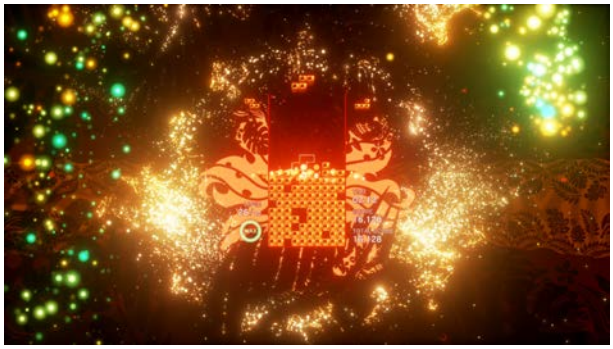
86 RockBand: `https://kotaku.com/ten-years-of-rock-band-that-game-everybody-used-to-pla-1820612`
Also has a VR version available: `http://www.rockbandvr.com/`

87 Tetris Effect VR: `http://enhance-experience.com/news/tetris-effect-coming-fall-2018-to-playstation4-with-optional-playstationvr-support.html`

88 MicrodoseVR gameplay footage: `https://www.youtube.com/watch?v=_SihX5mnCC0`
Beat Saber gameplay footage: `https://www.youtube.com/watch?v=NHD1utOvak8`
Tetris Effect VR gameplay footage: `https://www.youtube.com/watch?v=HO7CN_kmKlY`

(a) MicrodoseVR

(b) Beat Saber



(c) Tetris Effect VR

Figure 2.7: Several VR flow games[88]

Chapter 3
Concept Design

3.1 Concept

When considering how to best improve a person's subjective sense of well-being, one of the best methods is helping them cultivate flow in their life. The incredible effectiveness flow has on improving well-being alone makes it a worthy endeavor. That combined with how incredible the feeling is experienced phenomenologically gives it quite an advantage. This powerful concoction gives people both the ability to make their lives better in the long run while also having a great time doing it.

However, given how challenging the initial setup is in achieving flow, many people only experience it once they have spent an extensive amount of time in a preparatory phase (i.e., training skills and acquiring prerequisite knowledge). While their hard earned efforts are noteworthy, forgoing an effort to make such a valuable state of mind more accessible, on the grounds that such an experience must be "earned the hard way", would be a disservice to the betterment of humankind. It is still possible to experience growth even when the learning curve starts out easier. In fact, it will encourage people to keep growing instead of giving up. With the potential flow has to enhance the lives of others, I feel compelled to dive into the depths of the phenomenon of flow in order to bring more flow into our everyday lives.

With this perspective in mind, the goal of my research is to explore possible methods for lowering the barrier to enter flow, then create a system that utilizes such methods effectively. As shown in Chapter 2, VR is especially suitable for such a task. So, with VR as the foundation, and armed with an arsenal of methods to achieve a flow state, I designed a system that cohesively brings together various components of flow in order to make the experience more easily accessible.

3.2 Theoretical Frameworks for Designing Flow

In order to design an optimal flow system, we must create an experience with the right environment that will not only (1) create an opportunity to *enter* flow but (2) actively reduce all chances to *exit* flow as well. To that end, here I will outline my process to create such a system. First, I will outline the theoretical frameworks involved in the design. These frameworks provide markers that we can set as targets for the flow system–goals that the system should strive to achieve. After that, I will discuss the elements of my design that achieve those goals.

Qualities of Flow Revisited

Let's start with Csikszentmihalyi's nine qualities of flow.[1] The design must account for the three prerequisite qualities of the flow state: *a challenge-skill balance*, *clear goals*, and *immediate feedback*. Without these, we have little chance of creating even a weak flow experience as these three qualities are necessary to even enter a flow state.

Following that, the designer should do everything they can to create an environment where the user's mind can reside in the present moment and stay there. Without that, the player will definitely not be able to *concentrate on the task at hand*, experience a *merging of action and awareness* or a *loss of self-consciousness*. For example, if the experience requires users to dance but the users are shy, it's best to provide a secluded space for the experience in order for users to relax. Otherwise, they will be preoccupied wondering how others are judging them, thus prohibiting them from focusing on the present.

The system should also give users enough potential for interaction that they feel a *sense of control* over their experience.

Transformation of time is a natural occurring byproduct of the flow state. As such, there is no need to design around this quality.

Lastly, the system should be designed in a way that encourages *the autotelic experience* (i.e., intrinsic motivation). An example of this would be creating a fun educational game where players learn the necessary information while simultaneously having fun playing, making them intrinsically motivated to play.

In short, designers should make a system with (1) a challenge-skill balance, (2) clear goals, (3) immediate feedback, (4) an environment that encourages con-

1 (Csikszentmihalyi 1990)

centration on the present moment, (5) enough interaction to provide a sense of control, and (6) room for intrinsic motivation.

Flow Triggers Revisited

The other theoretical framework used in this thesis is Kotler's concept of flow triggers. This approach gives experience designers a more nuanced understanding of the conditions of an experience that promote flow. Because *internal triggers* so closely relate to Csikszentmihalyi's qualities of flow, there is no need to reiterate their benefits here. But for the sake of clarity, they match design qualities 1-4 in the above section: a challenge-skill balance, clear goals, immediate feedback, and an environment that encourages concentration on the present moment. With that said, let's examine the other triggers involved.

With the exception of social triggers, there are four other flow triggers: *high consequences*, *rich environment*, *deep embodiment*, and *creativity*. Experiences with *high consequences* will actively push users into a flow state by forcing them to focus on the present out of fear of potential injury. There doesn't necessarily have to be a real risk involved, as even a perceived risk will trick the body into releasing the same chemicals involved in focusing attention. The VR horror game, Dreadhalls[2] is a simple yet effective example of perceived risk. While creeping through darkly lit, confined corridors, there's no real risk to the player involved. However, players will quite quickly experience heightened concentration as the high quality sound design warns of extreme danger potentially lurking in the shadows around every corner. This experience design bypasses conscious control and affects the subconscious system of the body directly.

Rich environments combine novelty, unpredictability, and complexity as an additional method to focus our attention much like situations with *high consequences*. The important consideration to keep in mind here is to ensure that the player is capable of overcoming the problems faced in such an environment without having to think so much that they leave the present. If the user encounters a situation they can't quickly (i.e., almost automatically) figure out, they will break out of flow. Dance Dance Revolution (often referred to as DDR)[3] excels at creating such an environment. As the arrows fall quickly down the screen, the

2 Dreadhalls: `http://www.dreadhalls.com/`

3 Dance Dance Revolution: `https://en.wikipedia.org/wiki/Dance_Dance_Revolution`

player usually does not know which direction the arrows will point ahead of time. However, a skilled player, once they perceive the arrow with their eyes, will know exactly what to do with that information: where to step at what time.

Deep embodiment refers to experiences that require one to process a large amount of sensory data at once. This could be due to external input, such as loud music and expansive visuals typically found at raves. Or, the awareness could be enforced internally, as necessitated by the rules of a game. An example of this would be Twister[4], where players must be keenly aware of many parts of their body in order to make decisions that won't make them fall over as they try and move a body part to another part of the mat.

Lastly, *creativity* uses a combination of uninhibited risk-taking with pattern recognition to enhance focus.

When used successfully, these *internal*, *external*, and *creative* flow triggers rapidly accelerate an individual's ability to get into a flow state.

3.3 Flow Design Elements

Now that the theoretical frameworks have been described in the context of experience design, I will outline the elements I used to design my concept to induce flow that utilize such frameworks.

Virtual Reality

VR brings the user to a new place, totally separate from ordinary life, which better allows players to forget about their daily struggles. This encourages focus on the present moment. It also blocks out all visual and audio information, further preventing someone from being distracted by concerns of the real world. VR gives designers full control over the user's audio/visual experience. They can create high quality experiences that are novel, immersive, and powerful. In addition, high end head-mounted displays (HMDs) like the HTC Vive[5], Oculus Rift[6], and Playstation

4 Twister: `https://en.wikipedia.org/wiki/Twister_(game)`

5 HTC Vive: `https://www.vive.com/`

6 Oculus Rift: `https://www.oculus.com/`

VR (PSVR)[7] (see Figure 3.1) give players a more embodied experience with their respective 6DOF hand controllers. This gives players a much stronger sense of control while also making the world more "real" by creating more intuitive, 3D interactions with less abstractions.

Figure 3.1: Current generation high-end VR HMDs

Cross-Modality

Cross-modality, a term that describes the blending of multiple sensory modalities together, creates more order, harmony, and unity within a system. When everything connects, users won't be distracted by some random, out of sync object. This element removes distractions and avoids triggering unwanted instances of catching the brain's attention that would distract users. Cross-modality also enhances immersion, presence, and awe by doing something that does not usually happen in everyday life.

Music

Music is a great catalyst for flow. It synchronizes the user's experience, thus creating order in consciousness. It also induces a highly emotional experience, which would improve engagement with the experience.

7 Playstation VR: `https://www.playstation.com/en-gb/explore/playstation-vr/`

Movement

Movement creates a deep sense of embodiment that, along with music, synchronizes the experience.

Creation

Creation builds off of creativity, a key flow trigger. It creates an intrinsically rewarding experience. Creation keeps players engaged in an activity for an extended amount of time because possibilities seem endless as long as the player is willing to explore and take risks. It also gives players a chance to grow at their own pace. This element interacts intuitively and dynamically with the music and movement elements.

These design elements have been matched up with Csikszentmihalyi's qualities of flow and Kotler's flow triggers to paint a clearer picture. See Figure 3.2 below for reference.

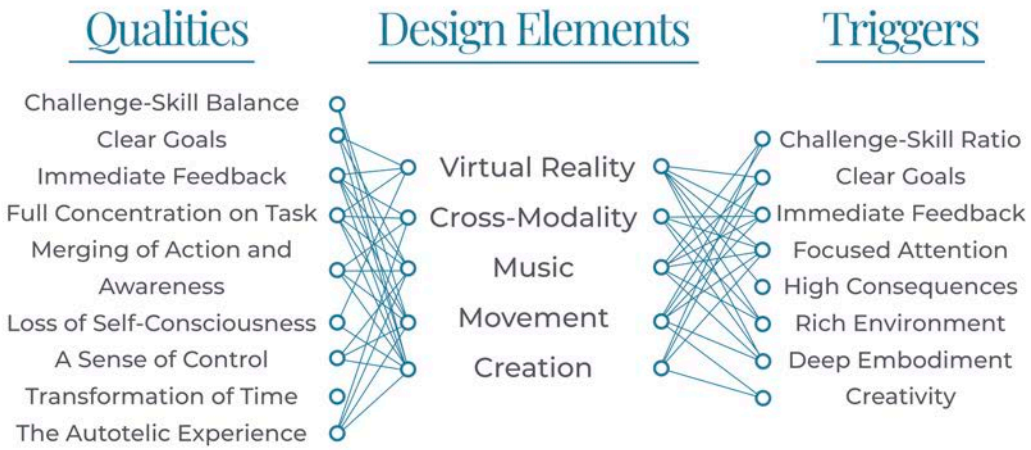


Figure 3.2: Design elements matched up with flow qualities and flow triggers

Chapter 4
Flow Zone

Using the parameters to induce flow described in chapter 3, I designed Flow Zone, a cross-modal music creation VR experience. The process of developing Flow Zone will be discussed in this chapter. I will describe the experience design, give an overview of the developed system, then explore the prototypes created to test potential methods to induce flow in VR.

4.1 Experience Design

The Vision

In Flow Zone, users are transported to a musical wonderland that bursts to life at their fingertips. Their bodies become the instrument, or catalyst, to produce

a harmonious symphony of sounds. As these sounds are created, synchronized visual and haptic sensations weave into the mix to create an immersive, complex, cross-modal music experience that enrapture users in the present moment. The music is a product of their own creativity. They are in control of the world they are creating. By moving in different sequences and exploring the space around them, the music will change and adapt to their play styles creating a joyful experience with possibilities as endless as their imagination. And as this is in VR, Flow Zone removes all worries and possible distractions from the world so the only thing on a player's mind is their private music world.

Target Users

There are a few types of people who will benefit most from Flow Zone. The first are those who enjoy dancing–or exploring movement with their bodies–to music. While usually they are at the whim of another person creating music, in this experience users can have a dynamic interaction with the music. They are both the creators and those who reap the benefits of their creations. These people get an even more intimate connection with the music they so readily flow with.

The second type of people are the music creators: musicians, DJs, sound designers, etc. Their passion for creating beauty from sound takes on a new form here by making their bodies the instrument in which sound originates. With ears particularly attuned to the nuances of music, they will enjoy exploring the way their body movements shape the sound they hear. They will also appreciate the cross-modal effects, feeling their music come to life more immersively.

The third and final type is more generally applicable. It characterizes anyone with a willingness to explore something new with an open and eager spirit. These are people who embrace their inner child, who leave inhibitions and insecurities at the door, who naturally seek out the zest in life. These people will probably already have a high sense of well-being considering their disposition to life. Nevertheless, this type of person will still openly embrace and enjoy experiencing Flow Zone because it consolidates many qualities of a readily-joyful experience into one neat package.

Even if a user does not fall into any of these groups, the experience may still effectively induce flow in such a person because it factors flow into every aspect of its design. While the person may not be the perfect candidate, there is a likely chance they will enter some level of flow as long as they exhibit a willingness to enjoy the experience.

4.2 System Architecture

This section will describe the systems used for the final version of Flow Zone.[1]

System Overview

Here are the components of Flow Zone that the system must account for:

- Playing the VR application smoothly
- Tracking a player's body in space to analyze movement
- Creating music based on the player's movements
- Playing back the audio, visual, and haptic components of the music to the player

For this system to work, it's necessary to compliment hardware with software components. Therefore, next I'll specify the requirements from each category.

Hardware

On the hardware side of things, the system must be able to do a few high demand processes concurrently:

- Run a high-end VR application with at least 90hz frame rate
- Track 6DOF VR hand controllers
- Orchestrate music with a music sequencer digital audio workstation (DAW)

To do this, a high-end computer is necessary to run such applications. It should also be above the minimum requirements listed for the VR system as it must run the music sequencer DAW simultaneously. A VR Ready G-Tune computer[2] was used in order to meet the demands of such a system.

1 Whenever something is used that did not make it into the final version, it will be discussed in the relevant prototype section.

2 VR Ready G-Tune Computer: `https://www.g-tune.jp/ws_model/ocufes/`

The Oculus Rift CV1[3] was used to display the VR content. The choice to use the Oculus Rift CV1 was mainly because of the design of its hand controllers. The Oculus Touch controllers are well designed for any plain hand interaction. This is in contrast to the HTC Vive or PSVR controllers that feel more like holding onto a stick or tool. See Figure 4.1 for a comparison. This was an important design decision for Flow Zone because it uses an inspired form of poi as the player's main interaction with the virtual environment (VE). Poi naturally move freely at many angles in the hand, and over the design process it became clear that the HTC Vive controllers felt awkward in comparison to Oculus Touch controllers. Oculus Touch controllers have 6DOF and are tracked using at least two Oculus cameras. In order to make the experience smooth in full 360°, a third camera is necessary to track the controllers when the player's body occludes the controllers from the two front-facing cameras.[4]

Figure 4.1: HTC Vive vs. Oculus Rift CV1 controllers

Software

The real substance of Flow Zone is in the software. Here the VR application software and music sequencer DAW are discussed.

3 Oculus Rift CV1: `https://www.oculus.com/rift/`

4 An experimental 2-sensor setup may also be possible for 360° tracking: `https://support.oculus.com/188772188235494/`

Unity 3D

Unity[5] is a game engine that dominates the VR content development market.[6] Most of the Unity assets used in Flow Zone were custom made. However, some external resources were used as well, which I will list below:

- Ultimate VFX[7] helped in creating beautiful particle effects used for the music experience.
- Ultimate Sound FX[8] was used whenever an additional sound effect was needed that did not come from the music sequencer.
- Unity OSC[9] was used to communicate between Unity and the music sequencer DAW by sending information with the Open Sound Control (OSC) protocol. This way Unity could control which audio files and sound effects should play.

Ableton Live

Ableton Live[10] is a music sequencer DAW that configures the music that players experience in Flow Zone.

Max for Live

Max for Live[11] is a plugin for Ableton Live that extends its functionality and gives developers more control over Ableton Live.

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5 Unity: `https://unity3d.com/`

6 59% of VR developers use Unity: `https://venturebeat.com/2017/03/01/game-engine-ceos-talk-past-each-other-when-it-comes-to-statistics/`

7 Ultimate VFX: `https://assetstore.unity.com/packages/vfx/particles/ultimate-vfx-26701`

8 Ultimate Sound FX: `https://assetstore.unity.com/packages/audio/sound-fx/universal-sound-fx-17256`

9 Unity OSC: `https://github.com/jorgegarcia/UnityOSC/tree/master/docs`

10 Ableton Live: `https://www.ableton.com/`

11 Max for Live: `https://www.ableton.com/en/live/max-for-live/`

LiveGrabber

Livegrabber[12] is a set of plugins used to send actions from Ableton Live to any device on the network that supports OSC. This is used to communicate with Unity from the Ableton side, giving Unity control. It works in conjunction with Unity OSC. Livegrabber version 4.1 was used.

4.3 Prototypes

Prototype 1: Virtual Poi

Goal

Virtual Poi was the first step in exploring how to design a VR experience to induce flow. The goal was to test how it feels to have a dynamic interaction with music using the body in virtual reality.

Implementation

Our design was inspired by poi[13], equipment used in traditional performance arts by the Maori people in New Zealand. Poi are balls tethered by a string that people can swing around with their hands. They have become widely popular in the last few decades as a flow art[14] for being exceptionally capable of enabling flow. Thus, utilizing the physics of poi as a method to interact with music might be an interesting experience. In addition, creating a virtual version in VR removes the potentially dangerous situation of hitting the body with the physical poi, a situation inexperienced poi users find themselves in all too often.

I, along with Benjamin Outram, Ph.D, and a couple others, capitalized on the Junction Tokyo hackathon[15] to rapidly prototype this idea and accumulate a high number of user tests. We used an Oculus Rift CV1, Oculus Touch controllers, and a 360° tracking setup (3 Oculus cameras) as our VR setup. We only used Unity for the implementation.

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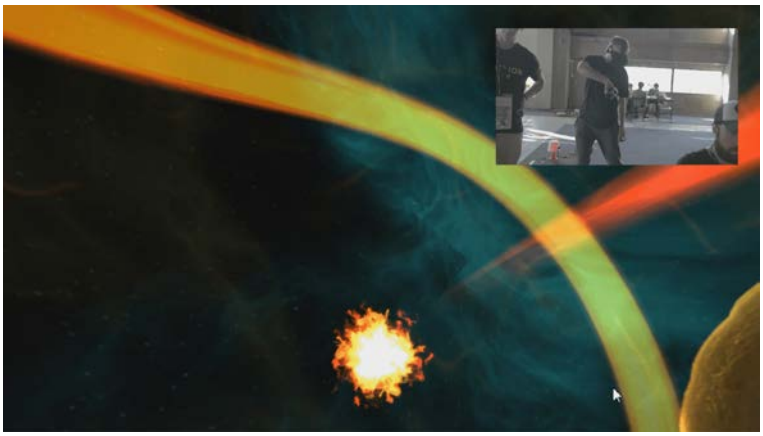
12 Livegrabber: `https://showsync.info/tools/livegrabber/`

13 Poi: `https://flowartsinstitute.com/discoveries-poi/`

14 Flow Art: https://listverse.com/2012/01/29/top-10-tools-of-the-flow-arts/

15 Junction Tokyo: `https://tokyo.hackjunction.com/`



(a) Gameplay

(b) Developing

(c) User testing

Figure 4.2: The process of developing and testing Virtual Poi at Junction Tokyo

We developed a VE that quantifies the energy the virtual poi outputs when users dance with them. We then coupled the energy level with the volume level of a music track playing in the game. Also, spheres equipped with 360° textures would grow and encompass a user's visual field at a speed coupled with with the poi's energy output. This created a sense of journeying through worlds with a soundtrack backdrop.

Insights

The feedback we received from over 30 user testers was mixed but overall positive. In general, people enjoyed exploring the physics of the poi and interacting with the music. However, novice poi users quickly became disengaged with the experi-

ence as they ran out of things to do. Experienced poi users showed great interest in the experience, spending a great deal of time in the VE. Users also considered the interaction with the music to be too simple, which also led to quick disengagement. In addition, a sizable portion of users said they got embarrassed during the experience as they considered how people might be watching them dance. This made them self-conscious and took them out of the experience. So, most users mentioned the the game has potential but is too simple in its current form.

From this prototype, I learned that virtual poi is a potentially powerful tool to induce flow, but it must be complimented with the right game design in order to be effective with users who are inexperienced with it. Also, a deeper interaction with the music may also lead to promising results. Lastly, VR can effectively remove people from their current environment, unless something about their actions makes them self-conscious about the potential judgments of bystanders. It's important to make sure the user feels comfortable with these judgments or given privacy in order for them to feel comfortable enough to forget about the world for the duration of the experience.

Prototype 2: Tunnel of Rings

Goal

This prototype was created to explore the relationship between flow and fast-paced gameplay, which here constitutes gameplay designed to make the user act so quickly they don't have time to think.

Implementation

To make such a game mechanic possible, we had to leave the previous prototype behind and start fresh. Benjamin and I created a tunnel using a procedural mesh script that Benjamin made for his other VR experience, Crystal Vibes.[16] We then designed a game where rings would rush toward the player from the end of the tunnel. Players would need to put either a hand or head (each body part using a tracked VR object, either an Oculus Touch controller or Oculus Rift CV1), inside the oncoming rings in order to win. We then tinkered with various game settings (e.g., ring movement speed and ring size) to create a fast and engaging experience.

16 Crystal Vibes: `http://www.benjaminoutram.com/crystal-vibes/`

Insights

Overall, the experience proved much less engaging than Virtual Poi. The experience succeeded in making players move so fast they only had time to react instead of thinking. Unfortunately, they often became uncomfortable due to wearing an HMD and overheating quickly. Also, the game wasn't very enjoyable. We decided it was better to stick with an enhanced version of Virtual Poi as people enjoyed the interaction with music and playing with the poi. However, we concluded it would still be valuable to explore other methods to encourage players to interact with the VE.

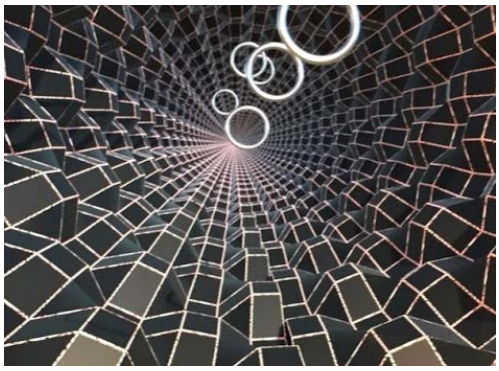
Prototype 3: Surrounding Circles

Goal

This prototype was designed to build off of some previous insights: the need to (1) explore other methods for players to interact with the VE to make it more engaging, and (2) make the poi mechanic more interesting and intuitive for inexperienced poi users. The goal then for Surrounding Circles was to utilize the poi as a core mechanic to gamify an interaction with the environment.

Implementation

I developed a VE in which many spheres were placed around the player at varying distances. Players used their poi to create circles, and a trail would be created following the location of the poi. If the player made a closed circle, the circle would activate, and any spheres located inside the sphere from the player's point of view (POV) would pop and be destroyed. This encourages players to interact with the environment and also learn how to create a high amount of energy with poi. Calculating the closed circle required translating the 3D space in Unity onto a 2D plane, the virtual midpoint ("third eye") POV between the player's two eyes. This way, the circle would be determined from the player's POV, which is necessary because the 3D shape the player makes could very well not overlap completely unless viewed from a 2D angle. Next, in order to determine which spheres were inside the enclosed circle's space from this 2D POV, raycasts were sent out from the player's POV. The sphere would be determined whether it was inside the enclosed circle using a dot product algorithm.



(a) Game footage

(b) User testing

Figure 4.3: The process of developing and testing Tunnel of Rings

Insights

This prototype was tested at Keio's KMD Forum[17], where again over 30 people got a chance to experience this game. I tested Surrounding Circles along with Virtual Poi to compare the feedback of users for each experience. Users enjoyed creating circles with the poi, but lost all means for utilizing creativity. They focused only on making lots of circles, popping all the spheres but never trying new methods. It became clear to me that this type of interaction had very a limited amount of affordance, as making circles was all they ended up doing. However, they did enjoy the clear goal laid out for them, which was to pop the spheres by making enclosed circles. This prototype provided users with both clear goals and immediate feedback, necessary prerequisites for flow. Unfortunately though, it didn't provide opportunities for growth.

Virtual Poi was considered by most to be more enjoyable than Surrounding Circles because of the interaction with music. Still, the feedback I received was a desire to have a richer interaction with it. They wanted to influence the music with their movements instead of it purely being a volume gauge for a prerecorded song. This insight inspired me to focus on music, and make creative interactions with music a core goal.

17 KMD Forum: `http://forum2.kmd.keio.ac.jp/`

Prototype 4: Flow Zone

Figure 4.4: Flow Zone showcased at the Dubai Internation Film Festival

Goal

Flow Zone was the first attempt to utilize all of the components of the design elements for flow listed in chapter 3. It was an attempt to give players an immersive experience with a rich and enjoyable interaction with music. It used poi and body movement as a means to give players control over the music they heard. It was designed to be fun and intuitive, with enough challenge to encourage development and growth. It needed clear goals with immediate feedback to meet the prerequisites for flow. In addition, it should be a rich environment utilizing deep embodiment to concentrate users on the present moment. Finally, it should make users intrinsically motivated to engage with the experience. All of these together would create a great recipe for flow.

Implementation

The system was composed of a constant dialogue between Unity and Ableton. Unity tracks the poi's energy output, and uses that data to communicate to Able-

ton what music to play. Based on the music playing, Unity creates visuals synchronized with the music to create a cross-modal music experience.

Each poi, hence each hand, was assigned two layers of music for a total of four layers. The right hand controlled the beat while the left controlled the melody. Each layer had an accompanying visual effect unique to that layer that was triggered by elements of the music. The energy output of each poi corresponded to three layers of sound. Each layer was added on top of previous layers.

- Tier 1: No energy: no music
- Tier 2: low energy - medium energy: music layer 1 activated
- Tier 3: medium - high energy: music layer 2 activated

In effect, this created six possible music combinations for players to experience.

Again, this prototype used the Oculus Rift CV1 and Oculus Touch controllers for VR.

Insights

For the first time, players got a deeper sense of the "magic" of flow. This was the musical interaction people had been asking for. Flow Zone was exhibited at the Dubai International Film Festival[18], and was played by over forty people (see Figure 4.4). Users finished hungry for more, and often expressed feelings of joy, relaxation, and happiness after playing. A couple users even considered the experience "therapeutic." Players would often repeatedly come back to play the game again because of how much fun they had in it. Many said they got lost in the music, dancing and losing track of time. From their descriptions, while unquantifiable, I gathered that this experience may very well be inducing flow in users.

This prototype effectively demonstrated that a cross-modal music experience based around creativity and expression was a viable solution to induce flow. Even in its simple, 4-layered state, people exhibited qualities of flow.

On the negative side, a number of people still felt shy dancing in a public space where others might notice them. The demo space didn't have any room for privacy. In order to really get into Flow Zone, people had to let go of their

18 Dubai International Film Festival: `https://dubaifilmfest.com/`

insecurities, which is quite challenging for people who are shy when it comes to dancing.

Prototype 5: Full Body Analysis

Goal

This prototype was made to test a more complex version of Flow Zone in which the whole body could be used as an instrument to create music. Instead of using poi, the goal was to use the arms, legs, and even the rest of the body in order to create a complex interaction with the music.

Implementation

To analyze full body movement, the full body must be tracked in VR. This was feasible using the HTC Vive, Vive controllers, and Vive Trackers with a Vive inverse kinematics system.[19] To test the effectiveness of such a system, first each hand was given a layer of music previously assigned to the left hand (i.e., a melodic layer) from Flow Zone, and each foot was given a track from the right hand (i.e., a beat layer). A new algorithm was developed to analyze someone's body movements over time using a Fourier transform. Each limb's movements were analyzed separately, and when a given energy threshold was reached, the music layer for that limb would play.

Insights

This prototype's development was stopped before completion because it quickly proved to be less effective than the Flow Zone prototype using poi as the core movement mechanic. While poi enabled users to easily create fluid, smooth movement, this full body movement had no such tool to make smooth movement more easily. Unless someone was already skilled at dancing, it was difficult for them to move in a way that smoothly transformed moment by moment. This prototype felt clunky by comparison. As the poi version (Prototype 4) was already superior, I decided it was best to work with that version moving forward. This prototype validated the effectiveness of using poi over other methods.

19 Vive Inverse Kinematics: `https://github.com/JamesBear/vive_ik_demo`

Chapter 5
Conclusion

This thesis explored the means to improve an individual's sense of well-being via flow by maximizing the powerful medium of virtual reality, then described the developed system using the findings from that research. In chapter 1, an overview was given that gave a background for why this thesis is important. It explained the potential flow has to improve well-being, and also the challenges of finding flow in life. It also signaled that virtual reality is a possible solution to overcome those challenges.

Next, chapter 2 examined the concepts of well-being, flow, and positive technology in depth. It showed that well-being can be categorized into both hedonic and eudaimonic types, and that flow is capable of improving both. Then, because flow is a complex phenomenon, the theoretical framework of flow was explored. Flow triggers were offered to give a nuanced understanding of the environments most helpful in inducing flow. The specific effects flow had on well-being were then discussed, along with the methods used to measure flow. Lastly, the technology designed to improve well-being was explored, showcasing the technology specifically designed for flow.

Chapter 3 described the concept of this thesis, then broke down the theoretical frameworks and particular elements used to design a system to induce flow.

Chapter 4 dove into the implementation of the system designed in chapter 3, which culminates in the Flow Zone VR experience.

In conclusion, Flow Zone explored the potential that VR has to induce the flow state. Limitations to this system leave several avenues for future work to be explored. Firstly, a full-body music interaction system may very well be more effective than Flow Zone's poi, but time constraints prohibited further examination in this thesis. Secondly, here the social aspects of flow were not explored, but group flow experiences are known to be very powerful. It's worth exploring the social elements of flow in virtual reality. Flow Zone may be enhanced with the implementation of multiplayer, and that prospect is currently unknown. Thirdly,

future research can explore the relationship cross-modal music experiences could have with an adaptive biofeedback system that responds to user's physiological data. I hope this research may provide a strong framework for the development of such systems in the future.

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