LIGHT BEYOND ILLUMINATION

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Light beyond Illumination:

Investigating the capability of Data Driven Ambient Light Visualizations for Increasing Social and Health Awareness by Informing people inside architectural spaces about the Social Media activities

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Executive Summary

This research demonstrates that in recent years, social media played a crucial role in informing people around the world about various social/health issues and spreading knowledge leading to increased awareness. It is unfortunate that the actions leading to raised awareness in the social media can only target people inside the digital world but not the people inside the physical space. Since many people deliberately do not take part in social media activities, they remain uninformed and neglected.

In this paper, we proposed to use ambient light visualizations, to display social media activities surrounding the most relevant social and health issues in public spaces. The aim is to inform people in the physical world, some of whom do not participate in social media but are eager to learn about different initiatives. Thus, encouraging them to seek further information about such topics.

It is shown that light visualization has the capability to convey information. Therefore, ambient light displays integrated in public space, can be used to raise awareness by informing people about the amount of attention towards a hot topic in social media in an unobtrusive way by displaying live data gathered from different activities such as the number of shares, comments, and likes. Learning about top social and health issues can encourage people to seek further information about these causes. By providing access to reliable resources via links, QR codes, or other means, people can reach accurate information resulting in raising public awareness.

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Introduction

Social media is becoming more and more important in our daily lives. Not only is the number of users of social media growing [1] but also the amount of time people spend on social media networks is increasing [2]. These numbers are only expected to increase [1]. This ever-increasing role of social media in human lives, made it an important platform to be used for raising awareness among people. In recent years social media played a crucial role in informing people around the world about various social/health issues and spreading knowledge leading to increased awareness [3].

It is unfortunate that the actions leading to raised awareness in the social media can only target people inside the digital world but not the people inside the physical world. However, many people deliberately do not take part in social media activities, and rightly so. There are a multitude of research and articles showing the concerns about and negative impact of social media on raising awareness. For instance, there is a growing concern about the lack of reliability and quality of the disseminated information on the social media platforms when it comes to healthcare (physical, mental or social). Recent data breaches have demonstrated that lack of confidentiality and privacy concerns are no longer theoretical or improbable. Furthermore, anonymity or reduced accountability have increased the risks associated with communicating harmful or incorrect advice. Even if the information turns out to be factually correct, information overload has made it very difficult for the users to correctly apply the information found online to their own specific situation [4].

These are some of the reasons why some people choose to not participate in the social media movement or even actively try to avoid it. It can now be seen that just like many other technologies; the spread of social media platforms is accompanied with advantages as well as disadvantages. Whether we are in favor of or opposed to the proliferation of social media, trends indicate that this technology is here to stay. Despite its numerous downsides, social media can be used a force to do good. When it comes to raising awareness in the physical world, visualizing social media data streams has a number of advantages over visualization of the factual information and trends about the cause itself.

For one, social media activity data streams tend to be much more dynamic (changing in real-time) and would thus result in a more attractive and visually pleasing visualization compared to the slow to update data streams that are derived from the governmental or organizational websites. Furthermore, studies have shown that simply informing people about various issues, or warning them of the consequences of their actions, is not very effective in encouraging them to change their behavior for the better [5]. Think about the warning labels on cigarette packaging which the study found to have no effect on decreasing the number of smokers. However, people tend to act with matching attitudes, beliefs, and behaviors to group norms in a psychological process called Conformity [6]. This can be taken advantage of by displaying the public consensus on various topics. Furthermore, learning a new language (visual language conveyed through ambient light) is a lengthy process. People need exposure over a long period of time to grasp all of the intricacies of this new language [7]. A visual language to convey various aspects of social media can be used in a wide variety of applications and as such the return on investing the time to teach this visual language is greater than for languages that must be changed depending on the context.

Thus, it should be our aim to exploit its benefits and to avoid its pitfalls as much as possible. One such benefit is the creation of a medium for raising public awareness. There is a vast number of people who deliberately do not participate in social media but would be eager to know about and even participate in such initiatives. This gap opens up an opportunity for raising public awareness visualizing data streams originating from social media activities around hot causes and issues. Being able to use the momentum around a cause in the social media space to inform the public within the physical world, would vastly increase the number of people that the cause can touch.

Here we investigate one possible way to inform people of such initiatives, unobtrusively, by only using social media as a source for relevant causes and their development over time. The aim is not to

try to convert people to become part of the social media movement, but rather to use it as a computational engine to identify the most important social and health issues in order to raise awareness regarding these causes in the real world.

Various persuasive techniques have been introduced for increasing human awareness using live data, often by informing people explicitly of relevant aspects [8]. An ambient light display could increase human awareness by conveying various information about some of the most pressing social and health issues within a relevant environmental context. Informing people inside an environment is only possible if they can grasp of the meaning of the light visualization. Therefore, it is important to investigate the possibility of using light as a medium to inform people, to see if people are capable of decoding social media data streams through light which is the primary focus of this study.

In brief, the author's aim is to study ambient lighting as a persuasive medium created by social media data streams with the intention to facilitate in raising health and social awareness. The focus of the research presented in this study is on exploring the potentials of using persuasive ambient light created by social media activities, and the possibility of conveying those meanings to the people inside architectural environments.

In order to achieve this goal, it is important to understand, and to investigate the capabilities of light to convey information. Therefore we look at two relevant sets of literature: (chapter 1) literature on the fact that social media can play in increasing social/health awareness; (chapter 2) literature on the role of light in conveying information; and lastly an experiment (chapter 3) examining the possibility of conveying social media meanings though light visualizations.

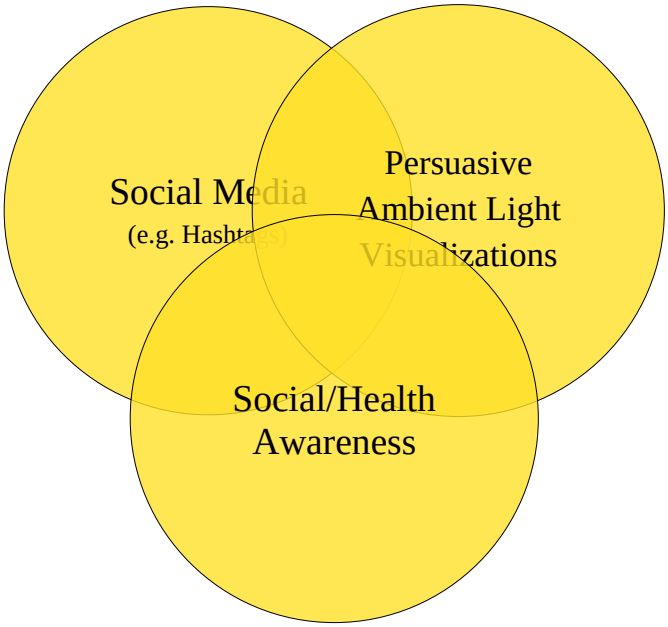
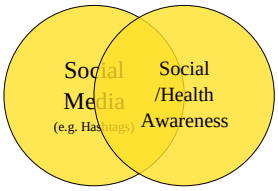


Fig.1: Illustrating the fields related to the research goal and suggesting the capability of creating a concept where there is an overlap.

Chapter 1: Social media vs. awareness

It is important to investigate the role of social media as one of the most popular platforms among people. Before starting to investigate the opportunities of using light to convey the meaning of social media data streams, we first need to understand the role that social media plays in creating awareness, the way individuals and organizations use social media to collaborate in order to promote such awareness, and the most recent and even futuristic approaches for raising awareness in the social media realm.



The role of social media in creating awareness: social media activism

Social media has been an enabler of information dissemination, collaboration and coordination for reasons ranging from personal to interpersonal. This has made social media the perfect platform for activism movements. Social media activism involves raising awareness and visibility for certain issues by using various tools sites like Facebook, Twitter, Instagram or Tumblr offer, such as posting, liking, sharing info, news and photos, re-blogging, commenting and sparking discussions and debates. Social media platforms have made mobilizing, coming together, discussing, organizing and protesting much easier than it used to be, especially through the effectiveness and rapidity of online communications, and the accessibility for both disabled and able-bodied people of different ages, genders, financial states, religions, and sexualities from around the world [9].

In social awareness and healthcare, the context we focus on, information dissemination is a key mechanism of creating awareness. For instance, it can be a crucial factor in the early understanding of a social issue or detection and prevention of various diseases. Specifically, in the healthcare domain, the social media phenomenon (e.g. the proliferation of social media tools such as Facebook, YouTube, Twitter) has created a new reality in health care, bringing social media to the forefront of health information generation and dissemination. By providing feedback and comments about their experiences with various drugs and treatments, etc., patients and their families have changed from consumers of Internet content to generators of information using social media sites [9].

As briefly mentioned before, this is not always beneficial. There are many risks associated with communicating incorrect advice, information overload, and the fact that such easy access to information may act as deterrent for patients to visit health professionals when necessary. Thus, it is important to note that, regardless of the over impact of social media on healthcare (whether positive or negative), there is a large momentum in favor of emboldening the role of social media in healthcare. The aim of this research is to be able to provide the information about the trends and relevant activities with regards to healthcare issues and causes, without promoting the direct use of social media, thus taking advantage of its strengths.

The journey of health awareness methods: a road to social media

In the old days creating health awareness happened through a variety of offline strategies, such as collaboration among clinicians from various countries [10] and collaboration through a network of community and university organizations [11] to develop educational programs and campaigns. Some research has also examined IT-enabled strategies such as webservices [12] for such collaborations. However, social media has characteristics that enable communication, collaboration, consumption and creation in entirely new ways [13].

Patients and their families use social media as a platform to share their experiences and their findings so others will become educated about similar conditions. They repackage the information they find for others and create forums for knowledge discovery and discussion [14]. For example, approximately two-thirds of posts in Facebook communities dedicated to diabetes

include unsolicited sharing of diabetes management strategies and over 13% of posts provide feedback to information requested by other users [15]. Social media provides a forum for reporting personal experiences, asking questions, and receiving direct feedback for people living with a disease. Through social media, support groups have found a new platform for organizing as patients and family caregivers share their experiences and connect with others [16]. Indeed, 620 breast cancer groups exist on Facebook, containing a total of 1,090,397 members. 46.7 % of these groups were created for patient/caregiver support [17].

More broadly, it has been shown that social media tools have enabled collaboration among individuals [18]. This can occur in such contexts as employees who work together within the boundaries of formal organizations, to contexts where dispersed individuals connect with one another through the support of a common cause. Now the question is, would social media remain as such an important platform or would it even grow as an important context to raise awareness?

Future position of social media in health awareness

The use of social media for health awareness studies demonstrate that a growing number of educational institutions are emphasizing and training future medical and allied health practitioners on the importance of using social media as an effective means to disseminate information amongst patients and clients. For example, nursing students have been encouraged to move beyond synthesizing pamphlets and flyers as a means of disseminating information to patients and have instead been equipped with resources to create 3-to-5 min YouTube videos to distribute using various social media platforms [19]. Moreover, a recent study demonstrated that utilizing Twitter and Facebook as supplementary tools for delivering educational content can be an effective way to engage medical trainees [20]. According to a recent study, 89% of 291 medical education course participants reported using social media, with most common platforms being YouTube and Facebook [21]. Professional medical societies such as the American Society of Clinical Oncology (ASCO) have been successfully using social media sites like Twitter to report clinical news from scientific sessions, to discuss treatment issues, and to facilitate a broader dialogue amongst physicians and healthcare professionals [22].

Overall, there is a growing pull amongst physicians to utilize social media as a means of ensuring the proper dissemination of information to their patients in order to counteract scientifically questionable publications and educational videos [23]. This means that the quality of the content varies drastically from excellent to spam and misinformation. As the volume of such content increases, the task of identifying high-quality content in social media sites becomes increasingly important and difficult [24]. However, by using social media activity related data streams, such as the engagement level, the most important topics can be identified. This when combined with directions towards a reliable and accountable body of information, steers people away from potential miss-information on the social media platforms and prevents information overload.

Previous sections described social media as a key element in raising awareness in the world we are currently living in, and the importance of its role is expected to increase in the future. But the question is: what the most recent developments in social media are which helped in raising awareness the most. Using these new features and methods, we can engage people from the physical world as well as digital one. In the next section the recent ways that social media impacted on people's awareness will be discussed.

Recent social media activities resulting in raising awareness: hashtag activism

Some recent activities in social media have created new opportunities to help in raising awareness. This powerful feature which has become very popular is relevant to the trends created

by Hashtags, which is called social media activism, or in other words hashtag activism [25]. During the past few years numerous hashtags such as #MarriageEquality made it to the top of the list of the most popular hashtags and helped raise awareness concerning social causes. One such trademark has been connected with the #BringBackOurGirls 2014 Chibok kidnapping of more than 300 Nigerian female students by Boko Haram that received millions of retweets, urging governments to take a stance and intervene. Another such example was #IamJada, after the sixteen-year old Jada Smart was raped and photographed and attacked by online trolls [26].
One other recent hashtag that had a great impact goes back to the time when actress Alyssa Milano tweeted, "If you've been sexually harassed or assaulted write 'me too' (fig.2) as a reply to this tweet", on Oct. 15, 2017. Her tweet has since received more than 50,000 likes, 25,000 retweets, and 60,000 responses and was a catalyst for the #MeToo movement. #MeToo has had a dramatic impact from Hollywood to Washington D.C. and from the board room to the dining room [27].

Fig.2

Fig.3

There are also plenty of hashtags used for raising health awareness. One of the most famous one was made in the Breast Cancer Awareness Month. On Pinterest, Avon Foundation launched a campaign called Pin It to End It, which donates $5 for every photo pinned with the hashtag #pinittoendit [28].

Social media has brought attention to numerous such issues and causes such as #LoveWins, #BlackLivesMatter (fig.3), #YesAllWomen, and #WeAreHere in ways traditional media has not [29]. The list of such campaigns gets longer each day as more people use social media to raise awareness and promote solidarity around a movement.

Conclusion

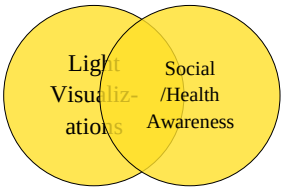
This chapter demonstrated that Social media is capable of providing a firsthand access to the biggest issues facing today's world, from those directly impacted to the people affiliated to them. Through the use of hashtags, social media serves as a powerful tool for people and movements to share their stories, and reach new audiences across the globe. Spreading top used hashtags, meaning the ones that the world pays the greatest attention to will remarkably help in raising awareness as it can reach more people.

It was also established that the impact of social media is not always positive. In fact, there are a growing number of concerns when it comes to privacy and dissemination of information on social media platforms. It was identified that many people avoid joining social media websites due to these amongst other concerns. These people are still interested in social and health movements that are discussed daily on social media platforms and would benefit from being informed about them in an unobtrusive way. As such, there is benefit in exploring a method to inform people in the physical

world of social media trends related to social and health causes, without the need to involve them directly in social media activities.

In this study, the process of bringing information inside the physical world will happen through ambient light visualizations of the relevant data streams related to the top Hashtags pointing to social/health causes. Most social media platforms, like Twitter and Facebook, have algorithms that track, follow, and promote the most popular – "trending" – hashtags, bringing pressing social matters to the spotlight [30], which will be utilized to find the top Hashtags and visualize the social media activities related to it.

Chapter 2. Light vs. awareness



Being able to convey information and data via light, will open enormous opportunities to improve human lives; one of these opportunities is using light to raise awareness. As the introduction pointed out, in this study ambient light has been chosen as a tool to be utilized in different environments to make people inside those environments aware of the top social/health topics inside the social media domain by representing the activities of social media users regarding those topics. But what does ambient light mean exactly and how can we implement it? What advantages does it have when raising awareness?

In this chapter, we provide a better understanding about ambient light and its strengths, light as a tool to communicate and the ways of conveying information through visual aids, and lastly some examples of the projects that tried to implement the idea of raising awareness via light visualizations.

Light as a tool to convey information

Since life evolved under the continuous influence of light, it is not surprising that practically all forms of life, including human beings, have developed a variety of responses to light and its characteristics. Light supports human beings functionally: it helps them to observe the world, but more interestingly, to obtain information.

More than 2000 years ago, the Greek already started using light as a communication tool by using sunlight reflected by shields to give orders to distance soldiers (fig.4). More recently, in the late 19th century, the heliograph was invented for instantaneous optical communication over long distances by flashes of sunlight reflected by a mirror (fig.5). Nowadays, we may no longer need shields or heliographs to send messages, but we still use light in many other forms of communication [31].

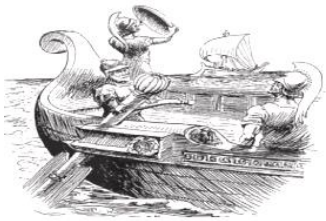


Fig.4

Fig.5

In the era we are living in, the integration of sensors, the Internet and lighting created systems that go beyond illumination. In particular, ‘‘smart’’ connected lighting systems have been introduced to the world which are capable of sensing and communicating vast amounts of information. This movement enabled light to become a window displaying those live data and therefore it gained a huge potential for creating context awareness. Also, the varying visual properties of light e.g., color, brightness,

saturation, position and frequency of changes [32], made light an ideal tool for encoding and sharing activity information.

Ways of conveying information via light

One of the ways light has been used to create awareness among people is through conveying information. Light can be visualized in various forms to inform people:

- Factual

Light can visualize factual information. Several efforts explored this type of conveying information, which allows users to judge for example levels of household energy consumption by displaying the numbers which represent the home's energy consumption (fig.6). It has been demonstrated that providing such information could persuade users to use less energy [33]. This type of conveying information needs the most attention among all and will provide detailed information for user.

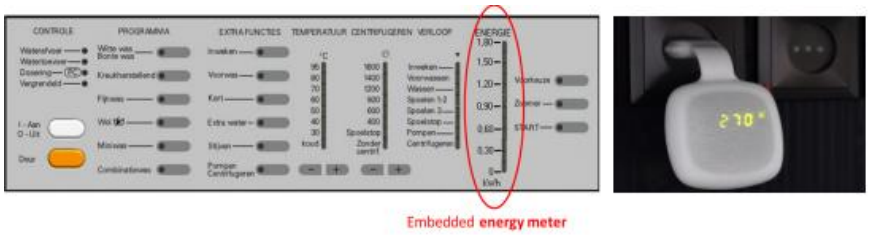


Fig.6: (left) energy meter and (right) Wattcher

- Graphical

Visualizing information in a graphical way will provide less information for the user, however the information will be conveyed faster and needs less attention to be understood. Earlier research suggested that applying graphical cues in many domains such as child education, health behavior and social interaction has a greater effect compared to the factual ones when the peed of conveying the information matters [34]. For instance, this form of informing has been successfully utilized in a social robot. This robotic agent could show signs of disapproval or negative social incentives (e.g., a sad face or a smiling face) as a feedback.

- Ambient

Ambient informing is a subtle and unobtrusive type of conveying information when compared to the previous two methods [35]. Furthermore, participants of an experiment reported that less cognitive effort was needed to understand information conveyed using ambient light thus suggesting that it can be quite cognitively efficient. Ishii and Ullmer (1997) suggested the use of ambient media such as sound, light, airflow, and water movement to act as background interfaces with cyberspace and work at the periphery of human perception. Given this definition, ambient informing has been investigated and applied in practice [36]. For example, an ambient device called Energy Orb (fig.7) was used to provide energy consumption information that changed color dependent on the time of-use tariff in operation (e.g., by glowing red when energy usage reaches a certain level and green otherwise). Another example of an ambient device is the Power Aware Cord (fig.8), which can visualize the current uptake of electricity of a connected appliance through glowing pulses, flow, and intensity of light [37]. The aim of the Power Aware Cord is to inform the user about the current consumption of various devices and thus persuade them to buy or use more power efficient types/brands. The cost of this information is of course a small increase in the power consumption and the environmental impact of the production and recycling process. However, with the growing ubiquity of energy efficient LEDs, the impact of increased power consumption can be minimized.

Fig.7

Fig.8

As described in above examples, ambient light can influence people in a subtle and unobtrusive way, and persuasive technology was shown to be effective while being at the "periphery of attention" [38]. Since in this study we are using ambient light as the persuasive technology for raising awareness, in the coming sections we are going to look deeper into the ambient light and its role in creating awareness.

Ambient light: as a peripheral awareness tool

The concept of ambient visualization or ambient display is defined as a category of data representations that conveys time-varying information in the periphery of human attention [8]. Peripheral vision, or indirect vision, is a part of vision that occurs outside the very center of gaze [39]. Receiving information via light in a peripheral way will create several opportunities:

- Prevents information overload: when compared to factual and graphical visualizations, ambient displays can remarkably reduce the amount of information mentally processed by providing an overview of the content by having information subtly portrayed in the periphery of one's attention [40]; meaning that people can perform their primary tasks in the foreground while simultaneously receiving context information in the background of their attention. It can be beneficial specially in the era that people often experience ''information overload''.

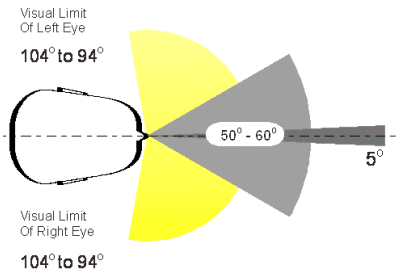


Fig.9: Horizontal field of view
Yellow field shows the peripheral vision.

- Capture more audience: Since ambient light is detectable by the periphery vision of human beings, it can help increasing awareness by grab the attention of more people. Conveying information in the peripheral field of vision (fig.9), which allows us to see without turning our head or moving the eyes [41], can spread among higher amount of audiences.

Data driven ambient light: creating ambient communication

> *"Humans have substantial ability to process ambient and peripheral information that directly affects our feelings and subconscious contextual understanding without the need to activate cognitive thought processes. By introducing meaningful digital feeds to our built environments through ambient communication we enhance and extend our conscious and subconscious awareness of what is going in around us." (Sapolsky 2017)*

Using ambient visualizations created by live data to convey information creates ambient communication within architectural environments. Light acts as an interface between the digital world and the psychical world, and the benefits for using digital content for lighting could be to render the invisible visible [42]. It could mean visual representation of weather, air traffic, social media traffic and much else in a calm and abstract way. When information transfers in an ambient manner, it does not draw attention, but it seeps in; we as humans have a huge ability to take that information in [43].

Such communication technology can be helpful in raising awareness. For instance, in the health domain, where users have to maintain an active lifestyle by tracking physical activity [44] or it can help in increasing awareness about maternal health [45]. Furthermore, in the domain of environmental sustainability, persuasive technology could create "energy awareness" [46]. More examples of such ambient informing have been mentioned in the following section.

Some examples of using data driven ambient light for raising awareness:

Particle Falls

This project reveals the presence and impact of particle pollution through a real time artistic visualization on the side of the building, in the form of a waterfall. The brighter and stronger the waterfall appears, the higher the concentration of particles in the air [7]. The vision for this project was to raise awareness amongst the public about air pollution. Since it measured in real time, it was able to show directly in what way human activity can make the air quality worse.

888 Collins Street

This project uses the building as a real-time weather display. The lighting design has two modes. The first mode displays the forecast for the following day, and in the second mode the building reflects the actual weather based on real time data provided by a weather station installed in the building's rooftop. The first mode is activated from dusk until midnight for five minutes at each full hour. The second mode is activated on all other times. The lighting responds to rainfall, cloud cover, wind speed and temperature. Low and high temperatures are displayed on the top and bottom of the building. Wind is displayed as light in turbulent motion and clouds as cloud formations on the top of the building, and if it is raining, the clouds change to visualize this [48]. In terms of sustainability it can be argued that similar results could have been attained with far fewer resources and a smaller carbon footprint.

Human BEEing

This temporary project demonstrates the use of digital placemaking technologies not only for connecting people with their cities, but also for raising awareness of global pressing issues [42]. The project wanted to create awareness over the very important role of the bees, which is to pollinate plants and produce honey. Of course, as we have seen before, the use of technology can also have negative consequences. For instance, the use of light projectors in this concept, creates light pollution which is found to disturb some animals.

Energy Tower Façade Lighting

The vision for this big power plant was to make a structure with the ability to communicate and relay messages of sustainable energy to the public" by displaying variations of dynamic light scenes in its facades. At night the backlight perforated façade visualizes the current power generation (directly correlated to consumption) capacity which transforms the incinerator into a gently glowing beacon - a symbol of the plant's energy production. Several times an hour a spark of light will gradually grow into a burning flame that lights up the entire building [49]. Unfortunately, this project also chose to consume a substantial amount of power to deliver its message of sustainability. It is still unknown whether the net results in terms of power consumption and sustainability is positive or negative.

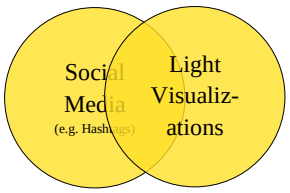
Conclusion

Understanding ambient light communication and the opportunities it can bring to human lives demonstrates that light has the potential to add a new layer to the environment, in a way that serves information and this information can be used for various applications. It was shown, that when compared to the more traditional factual and graphical visualizations, ambient light requires less cognitive effort from people and a produces a higher impact on their behavior.

If we want to use ambient communication to create awareness, the effect can be powerful only if the message is clear and interpretable by people inside the environment. However, ambient representations can be quite ambiguous and might be hard to interpret [8]. As such we must endeavor to make the ambient light visualizations as easy to grasp as possible and test it under real world conditions before implementing in our products.

Finally, we saw a few examples of projects were ambient light communication was used to convey information. It was also apparent that some of these projects did not consider all of the impacts (specially the negative ones) and that even though they delivered a message of sustainability, they often did so in unsustainable manners. Care must be taken in order not to repeat their mistakes.

CHAPTER 3: Light visualizations vs. Social media meanings



In this study we decide to spread awareness regarding the top used Hashtags among the people in the physical world using ambient light visualizations. Since the main intention is conveying the meanings of social media activities to the people, it is important to investigate the understanding of the people regarding different light visualizations. Therefore, in this chapter a test has been designed to evaluate the possibility of informing people about social media activities through light.

An important step in the design of visual languages is the categorization of the graphical objects and the composition rules for constructing feasible visual sentences. The presence of different typologies of visual languages, each with specific graphical and structural characteristics, yields the need to have tools that unify the design steps for different types of visual languages [50]. In this chapter, the process of selecting visual variables and creating visualizations which are used to convey information about social media data is outlined.

The hope is that the result of the test can be used directly to construct a visual language for expressing social media activities. However, for the scope of this thesis project, the ultimate goal of the test, is to conclude whether it is possible to convey the meaning of concepts of social media, using light visualizations.

Background:

Visual variables

In order to prove that ambient light is able to convey information, we need to understand how we can encode information in the form of light visualization. This section contains a review of literature which examines the visual variables that can be varied to encode information. These variables can be divided into two groups: static variables that describe the graphic dimensions that are invariant to time [51], as well as dynamic variables that encode information in the temporal dimension. The final goal is to compile a list of suitable visual variables that can be played with to create the visualizations.

"The nature of the pigments provides the basis for sensations of light and colour; that is, brightness, hue and saturation. The geometrical demarcation of these qualities provides the physical basis for perception of areas and their shapes. Altogether, these factors constitute the vocabulary of the language of vision, and are acting as the optical forces of attraction." [52] In this quote, Gyorgy Kepes, lists several visual attributes. These visual factors have been picked up by many designers and authors ever since. Jacques Bertin subsequently extended and proposed a new list that contains: *position*, *direction* and differences in *size*, *shape*, *brightness*, *colour* and *texture*. Over the years, the body of knowledge concerning this topic has increased drastically. Figure 10 outlines the visual variables that have been added to the language of vision in the field of cartography. For instance, Morrison proposed the addition of new variables: arrangement and saturation (third dimension of color). Another important turning point was when MacEachren realized that the basic visual variables distinguished by Bertin were insufficient to visualize the phenomenon of uncertainty, and for this reason he proposed additional variables: crispness, resolution and transparency.

Static visual variables

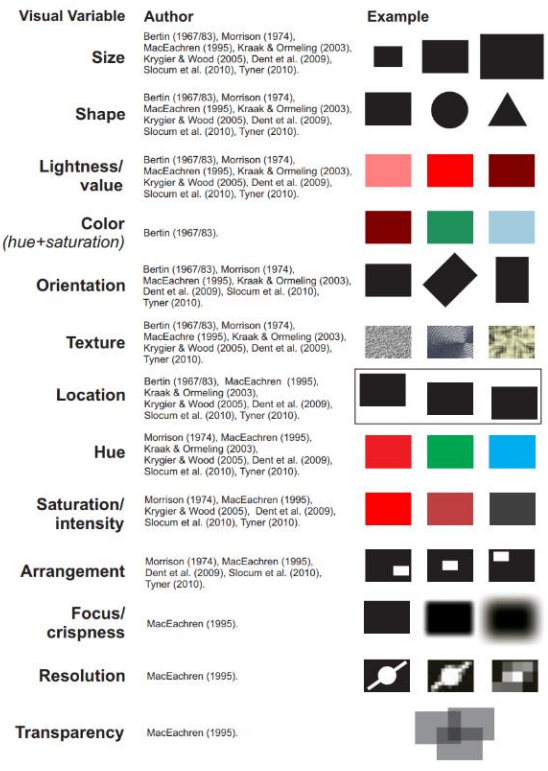


Fig.10. Breakdown of static visual variables

Thus, given the mentioned literature, a list of static visual variables was compiled. Table 1 provides an overview of these variables. This table does not aim to be a comprehensive list of all static visual variables, but it covers the primary variables that are mentioned and used by the researchers.

Variable	Description
Size	Size describes the amount of space occupied by the graphic object.
Shape	Shape describes the external form (i.e., the outline) of the graphic object. The shape can vary from highly abstract, such as circles, squares, or triangles, to highly complex geometries.
Lightness	Lightness describes the relative amount of energy emitted or reflected by the symbol. Variation in color value results in the perception of shading, or areas of relative light (high emission) and dark (low emission). Accordingly, color value is sometimes referred to as "lightness" in color theory.
Color hue	the degree to which a stimulus can be described as similar to or different from stimuli that are described as red, green, blue, and yellow. This is one of three visual variables associated with the perception of "color."
Color saturation	**Saturation** is the "colorfulness of an area judged in proportion to its brightness", which in effect is the perceived freedom from whitishness of the light coming from the area [22]. This is the third of three visual variables associated with the perception of color. Bold or saturated colors emit or reflect energy in a concentrated band of the visible spectrum, whereas pastel or desaturated colors emit or reflect energy evenly across the visible spectrum.
Orientation	Orientation describes the rotation of the graphic object from "normal." The normal orientation typically is relative to the neat line (either explicitly included or inferred by negative space), but in some cases it can be relative to the projected spatial coordinate system
Texture	Texture is a higher-order visual dimension with three constituent components: the directionality of the texture units (related to the visual variable orientation), the size of the texture units (related to the visual variable size), and the density of the texture units (approaching the perceptual effect of shading associated with the visual variable color value).
Location	Location describes the position of the graphic symbol relative to a frame.
Arrangement	Arrangement describes the layout of graphic objects constituting the whole. The visual variable arrangement varies from regular to irregular.
Crispness	Crispness describes the sharpness of the boundary of the graphic object. Crispness also is referred to as the inverse of "depth-of-field" and "fuzziness" in information visualization.
Resolution	Resolution describes the spatial precision at which the graphic object is displayed.
Transparency	Transparency describes the amount of graphic blending between a graphic object and the background or underlying graphic objects.

Table 1. Definition of visual variables [53]

Dynamic visual variables

Even though Bertin did not have a lot of confidence in the usefulness of dynamic maps. He stated, even as early as 1967, that motion would dominate the graphic variables he distinguished (size, value, grain, color hue, orientation and shape), thus revolutionizing the effectiveness of the field of cartography. Recent research confirms Bertin's opinion by showing that visual variables can indeed be used on the individual frames of an animation in such a way that these images effectively communicate a message to the user, while the movement of the animation gives the message an extra dimension and "new energy" [54] . Furthermore, the findings of Koussoulakou showed that using animated graphics helped users grasp the contents of a message in a more effective manner compared to using traditional static visualizations [55].

It has become clear that the traditional visual variables, which we called the static visual variables, do not suffice in describing the added depth of information that we have available today. To this end six "new" dynamic visual variables were introduced by MacEachren in 1994

[56]. These are: moment, duration, frequency, order, rate of change, synchronization. Table 2 provides an overview and description of these variables.

Variable	Description
Moment	The moment that a graphic object changes during an animation can be used for temporal as well as non-temporal animations.
Duration	Duration indicates the duration in real-time a graphic object is visible during an animation. For instance, if province A has twice the amount of annual sunshine of province B, province A would be highlighted twice as long during the animation.
Frequency	The dynamic visual variable frequency uses the rate of occurrence of graphical elements.
Order	Animation actually is the presentation of individual frames in a given order. Chronologically showing temporal data is probably the most used form of animation.
Rate of change	The rate of change can be described as M/D, where M is the change magnitude and D is the duration for that change.
Synchronization	With synchronization two (or more) phenomena are related to each other by showing their development synchronously in one animation.

Table 2. Description of Dynamic Visual Variables

Data categories

As previously mentioned, in this study, it is intended to represent social media activities. The changes and trends in this data is what we want to convey using ambient light visualizations. However, social media platforms have a wide range of data streams. To simplify, we can attempt to categories these data streams based on their similarities. It is hoped that the same visualization can be then be used successfully to convey the meaning of any of the data streams within the same category.

In order to come up with a reasonable number of categories to assign to different data streams, 5 of the most commonly used social media platforms (Facebook, YouTube, Instagram, Twitter, LinkedIn) [57] was selected. Subsequently, a list of all of the data streams for each social media platform was compiled and clustered based on similarities. Finally, according to the literature study regarding the different social media categories, the most appropriate names have been assigned to the clusters which resulted in the 9 data outlined in table 3.

Data Category	Description
Reach	Number of times a post has been exposed to the users.
Approach	Number of clicks in order to view a post.
Transience	Ratio of average minutes watched per view over the total time length of the post.
Engagement	Ratio of the number of likes and comments over the 'total number of views' (approach).
Distribution	Ratio of the number of shares and mentions over the 'total number of views' (approach).
Growth	Change in the number of followers, friends, or subscribes.
Achievement	Special event, like when a post receives the highest number of likes.
Historic Legacy	The number of times a Hashtag has been used or searched for.
Composition	Arrangement of the users' specifications, like gender

Table 3. Data categories' definitions

Methodology:

This chapter provides an overview of the methods and procedures used in this test. This should allow future researchers to reproduce and extend the experiment in order to improve upon the results

achieved within the limited time and scope of the project. A detailed description of the visual stimuli, participants and test procedure is outlined below.

Stimuli

A number of static and dynamic visual variables were identified in the previous section which can be
used to encode information. According to the literature study, these variables are: Size, Shape, Colour value, Colour hue, Colour saturation, Orientation, Texture, Location, Arrangement, Crispness, Resolution, Transparency, Moment, Duration, Frequency, Order, Rate of Change, and Synchronisation.

Given the fact that the visualizations are intended to be displayed using a screen, some of the aforementioned variables are either impossible to demonstrate or reduce to the same variable. In this test, it was decided to use a vertical line as the main graphic object. This fixes the variables **Shape** and **Size**, thus removing them from the design space for developing the visualizations. This was done to reduce the scope and thus the complexity of the test by a considerable margin. A line is the simplest geometrical shape (it's considered one dimensional in this context) which is the reason why it was selected. Any shape that defines both a vertical as well as horizontal boundary would also require 2 parameters to define its **Size** and **Location**. While a line requires one (width and position along the horizontal axis) making it easier to map to most quantitative information. This leaves room for improvements in future research.
Furthermore, **Texture** is also eliminated as variable as the aim of the project was to communicate information using ambient light. Light reflecting off a surface cannot represent **Textures**. The visible **Texture** is a property of the surface reflecting the light and its control is out of the scope of this test. **Focus** and **Resolution** carry the same effect when it comes to visualizing with light; therefore, in this study **Focus** has been chosen since it has a better similarity to blurriness which is a light property. Similarly, **Transparency** and **Lightness** (of the foreground graphic object)**,** as defined in the previous section, become equivalent when using light visualizations.

Lastly, regarding the dynamic visual variables, due to the complexity and the number of visualizations required to cover all these variables, it was decided to focus on a few of the more distinct variables. **Synchronization** was not used as only a single graphic object (the line as described above) is displayed. Furthermore, **Moment** and **Duration** represent two sides of the same coin and thus are captured on every visualization as such there are not isolated in their own specific visualization.

Due to the above reasoning, the final selection of the visual variables for creating the light visualizations for this test are as below: **Size**, **Lightness**, **Colour**, **Location**, **Saturation**, **Focus**, **Moment**, **Frequency, Order, Rate of change**. From these variables, 9 visualizations were created (fig.11). These visualizations are designed to incorporate and display one or more of these variables. Since, these variables are varied frame by frame, it is vital to also consider the inverse order for each visualization. Hence, each visualization is created as a pair of converse animations (see *Appendix A*).

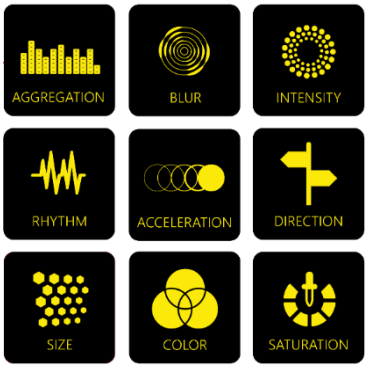


Fig.11

Some visualizations have been made using POET software which is a real-time generative content editor that facilitates creating visualizations using live data streams [58]. Other visualizations were created using a Python script and a simple game engine library (PyGame).

Procedure:
Now with a set of light visualizations and data categories at hand, we can establish a test procedure to explore which data category the participants would perceive after watching each visualization.

The test consists of two phases: Answering an online questionnaire as well as the complimentary interview. At first, a short introduction is provided to each of the participants. The aim of the introduction is to explain the meaning of the social media categories, as well as the test procedure and survey layout. Next, the participants will be asked to fill in an online survey after reading and signing the informed consent form (to use the results of the survey for the purpose of this project). The participants were also given an estimation of the time required to complete the questionnaire and an e-mail contact in case they had any questions or doubts.
SogoSurvey was used as the online platform to host the questionnaire. There are 18 questions in total each corresponding to a particular visualization. At the top of each question, a short (5 second) visualization is displayed. The video is looped in case the participants want to have another look. It is important to note that before the start of the visualization, a brief message is displayed that counts down to the start of the visualization. This is done in order to ensure that a constantly repeating visualization does not produce unintended effects (such as conveying frequency etc.). Furthermore, the order of the questions is randomized to improve the accuracy of the results. This also helps combat the effect of participants losing focus at the end of the survey, thus providing less elaborate answers for the latter questions. Below each visualization, the participants have the ability to select one or more data categories that they perceive as being related to the displayed visualization. Each selection can be elaborated using a textual answer.
The next phase of the test is an interview with the participants. This will take place after the results of the participant was briefly analysed. This is done in order to focus on the more interesting answer due to time restrictions. The aim of the interview is to clarify any ambiguities in the provided answers as well as gaining other insights that may be triggered after a one to one conversation. It is important to only perform the interview after the survey has been fully completed, as to not influence the results.

Participants
In total there were 18 participants that took the survey. All participants were TU Delft Students, out of which, 8 were female and 10 were male. The age of the participants was between 21 to 31 with an average of 25. The participants originated from 8 countries, 3 of which is located in the European continent, 2 in America, with the final 3 being located in East Asia.

Results:
To be able to draw valid conclusions from the data collected through the experiment, it is important to summarize, process and visualize the data in a form that can best be analyzed. The analysis is broken down into two parts. The first part examines if each of the 18 visualization can be used as an effective method for conveying the meaning of one of the selected data categories. The distribution of the votes between the data category trends is the subject of the second part of the analysis. There, the possibility of using the 18 selected visualizations, as a means of conveying a sense of increase, decrease or constancy (here after referred to as data category trend) is examined. In each section, a quantitative analysis is performed based on the gathered numerical results (the number of votes for data categories and data category trends), as well as a qualitative analysis based on the interviews performed with the participants.

Visualizations vs. data categories
This part examines if each of the 18 visualization can be used as an effective method for conveying the meaning of one of the selected data categories. This is done by observing any outliers that fall

outside of the normal distribution of the dependent variable. There is a comprehensive analysis regarding this part which is included in *Appendix C*. The following sections are the conclusions derived from the analysis:

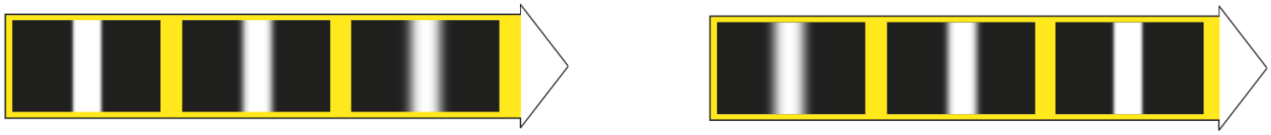
1) Aggregation

Normal **Inverse**

To summarize, this pair of visualizations is a good candidate to be used for representing **Distribution** in later designs, since both the normal and inverse visualizations conveyed a meaning of increase/decrease in Distribution. Furthermore, when considering the qualitative analysis, **Growth** and possibly **Reach** may present other alternatives. Due to the explanation of the meaning of **Reach** (the number of times a post has been exposed to the users); this data category can only increase therefore can be represented through the first visualization (Aggregation_Normal).

2) Blur

Normal **Inverse**



Unfortunately, this pair of visualizations do not share any common data categories. This means that even though each visualization by itself may be used to convey **Growth** or **Transience**, it is not very wise to use this pair to convey and increase or decrease in any of the data categories. The qualitative analysis also confirms the quantitative analysis (i.e. participants cannot associate these visualizations with an increase or decrease). Blue_Inverse can however be employed by itself for conveying Transience (for instance approaching the end of something).

3) Intensity

Normal **Inverse**

The results show that this pair of visualizations is an ideal candidate to convey **Growth**. The converse pair also performs very well when conveying a sense of increase or decrease leaving little ambiguity when it comes to these two visualizations.

4) Rhythm

Normal **Inverse**

Unfortunately, this pair of visualizations do not share any common data categories. This means that even though each visualization by itself may be used to convey **Engagement** or **Transience**, it is not

very wise to use this pair to convey and increase or decrease in any of the data categories. The qualitative analysis also confirms the quantitative analysis (i.e. participants cannot associate these visualizations with an increase or decrease) or even a common data category.

5) Color

Normal

Inverse

This pair of visualizations is a good candidate to be used for representing **Composition** in later designs. However, nothing can be concluded regarding the trend of the data category. Most people perceive cannot associate a change in color to an increase or decrease. This fact is quite intuitive when considering the fact that composition is defined as a ratio of constituents where the total is always constant.

6) Direction

Normal

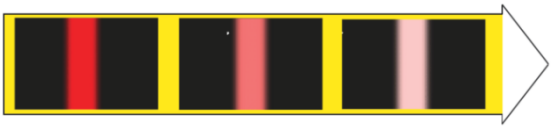
Inverse

Reach is the only common data category that can be conveyed using this pair of visualizations. The qualitative analysis also shows that given a similar target group (with regards to the native language they use) a sense of trend (increase/decrease) can also be reliably conveyed.

7) Saturation

Normal

Inverse



Adding the insights gained from the qualitative analysis as well as the results from the quantitative one, **Achievement** is the leading candidate to be conveyed using this pair of visualizations. **Composition** is another alternative data category that may be used successfully.

8) Acceleration

Normal

Inverse

Unfortunately, this pair of visualizations do not share any common data categories. This means that even though the two visualizations by themselves may be used to convey **Reach/Engagement** or **Growth**, it is not very wise to use this pair to convey and increase or decrease in any of the data categories. The qualitative analysis (combined with the quantitative results) suggest that **Growth** can be conveyed somewhat successfully with this visualization, but further research is required.

9) Size

Normal

Inverse

Unfortunately, this pair of visualizations do not share any common data categories. This means that even though the two visualizations by themselves may be used to convey **Reach/Approach** or **Growth**, it is not very wise to use this pair to present any of the data categories. The qualitative analysis (combined with the quantitative results) suggest that these visualizations are excellent for conveying a trend (increase/decrease) however.

Visualizations vs data category trends

The distribution of the votes between the data category trends is the subject of the second part of the analysis. In this section, the possibility of using the 18 selected visualizations, as a means of conveying a sense of increase, decrease or constancy (here after referred to as data category trend) is examined. The analysis of this section has been thoroughly explained in the *Appendix D*.

Increase/Decrease

The key in finding a good visualization for conveying a sense of increase or decrease is to find a pair of converse visualizations that show an inversely proportional relationship when we observe its number of votes. To clarify, this means that whenever a visualization receives a high number of votes for increase, its converse visualization should receive a low number of votes. Similarly, when looking at the number of votes for decrease, this pair of visualization should present the opposite results. Any pairs of visualizations that this illustrate behavior is an ideal candidate to convey increase and decrease in a reliable manner.

It has been observed that the following visualizations received more votes than the mean and median value: **Aggregation, Blur (inverse), Intensity, Rhythm (irregular), Saturation, Acceleration** and **Size**. Out of these visualizations, the number of votes for **Aggregation, Intensity, Acceleration** and **Size** show a statically significant result. Furthermore, their converse visualization has a number of votes that are far below the mean and median. These four visualizations are excellent candidates to convey a sense of increase.

On the other hand, **Aggregation (inverse), Blur (inverse), Intensity (inverse), Direction (left to right), Saturation (inverse), Deceleration** and **Size (inverse)** have received more votes than the mean and median values. Out of these visualizations, **Aggregation (inverse), Intensity (inverse), Saturation (inverse)** and **Size (inverse)** show statistically significant results by obtaining enough votes. Moreover, their converse visualizations have received less votes than the mean and median value of votes.

Comparing the above 2 sets of visualizations, it can be observed that **Aggregation, Intensity** and **Size** are form pairs of visualizations that indeed display the all of the requirements to be used as a method to convey a sense of increase and decrease reliably. Though not as statically significant, the results hint that **Saturation** and **Acceleration** can also be used successful for this purpose. As mentioned before, interviews show that the color used to display **Saturation** and the direction of motion for **Acceleration** play an important role in how they are perceived. Further research is advisable to draw more concrete conclusions with regards to the suitability of these two visualizations.

Constant

If one needs to convey the meaning of one the selected data categories without an associated sense of increase or decrease, which visualization is suitable? This section aims to answer this question. From the test results, it can be observed that the following visualizations received more votes than the mean and median value: **Blur (inverse), Rhythm (regular), Rhythm (irregular), Color (red to blue), Color (blue to red) and Direction (left to right)**. With the exception of **Blur** and **Direction**, the other 4 visualizations form a pair (**Rhythm**, **Color**), meaning that both the normal as well as the converse visualizations do not seem to convey any sense of increase or decrease. These visualizations can be used with other visualization to provide additional information without affecting the overall sense of trend.

Conclusions

In this section, all the knowledge gathered from the quantitative as well as qualitative analysis of the results is combined in order to see if the objectives of this test have been accomplished. As a reminder, this experiment was established and performed to conclude if the selected data categories can be conveyed using any of the prepared visualizations. The results showed that most participants did indeed have a common perception of some of the data categories. This means that the participants shared a common understanding of these visualizations which suggests that in more general terms, light visualization can be used to form a very basic language to transfer information.

The results for some of the data categories were more concrete than others. For instance, Distribution, Growth and Composition are best displayed using Aggregation, Intensity and Color, respectively. Achievement can be conveyed by using Saturation provided more that an appropriate color is selected. This of course is a good subject for further study. Furthermore, Transience can be displayed successfully by Rhythm if there is no need to also convey a trend in this data category. The results also showed that a pair of converse visualization may be used for conveying 2 different data categories. For instance, Acceleration and Deceleration can display Engagement and Growth, respectively. This knowledge can be applied in more specific cases by designers.

Lastly, it was also shown that data trends (increase/decrease) are best expressed using Aggregation, Intensity and Size, and that people tend to get a sense of constancy from a shifting color or regular/irregular movements. This experiment does not fill every gap in our current understanding of the subject. In contrary, a lot more research is required in this area to be able to define the building blocks for this new language. However, the results of the experiment should provide a solid foundation for future researchers.

Data Category	Visualization
Reach	Aggregation (Normal), Intensity (Normal), Direction (Left to Right), Direction (Right to Left), Acceleration (Normal), Size (Normal)
Approach	Rhythm (Regular), Size (Normal)
Transience	Blur (Inverse), Rhythm (Irregular), Direction (Right to Left)
Engagement	Rhythm (Regular), Acceleration (Normal)
Distribution	Aggregation (Normal), Aggregation (Inverse)
Growth	Blur (Normal), Intensity (Normal), Intensity (Inverse), Direction (Left to Right), Acceleration (Inverse), Size (Inverse)
Achievement	Color (Red to Blue), Saturation (Normal), Saturation (Inverse)
Historic Legacy	-
Composition	Color (Red to Blue), Color (Blue to Red), Saturation (Normal), Saturation (Inverse)

Table 4. Selected Visualizations for each Data Category

Chapter 4. Conclusions

After demonstrating the crucial role of social media in informing people around the world about various social/health issues leading to increased awareness, and focusing on the neglected people who are not the users of social media, it has been decided to inform people in physical spaces about various hot topics inside the digital space. As a result, more people can become aware about different social/health issues (fig.12).

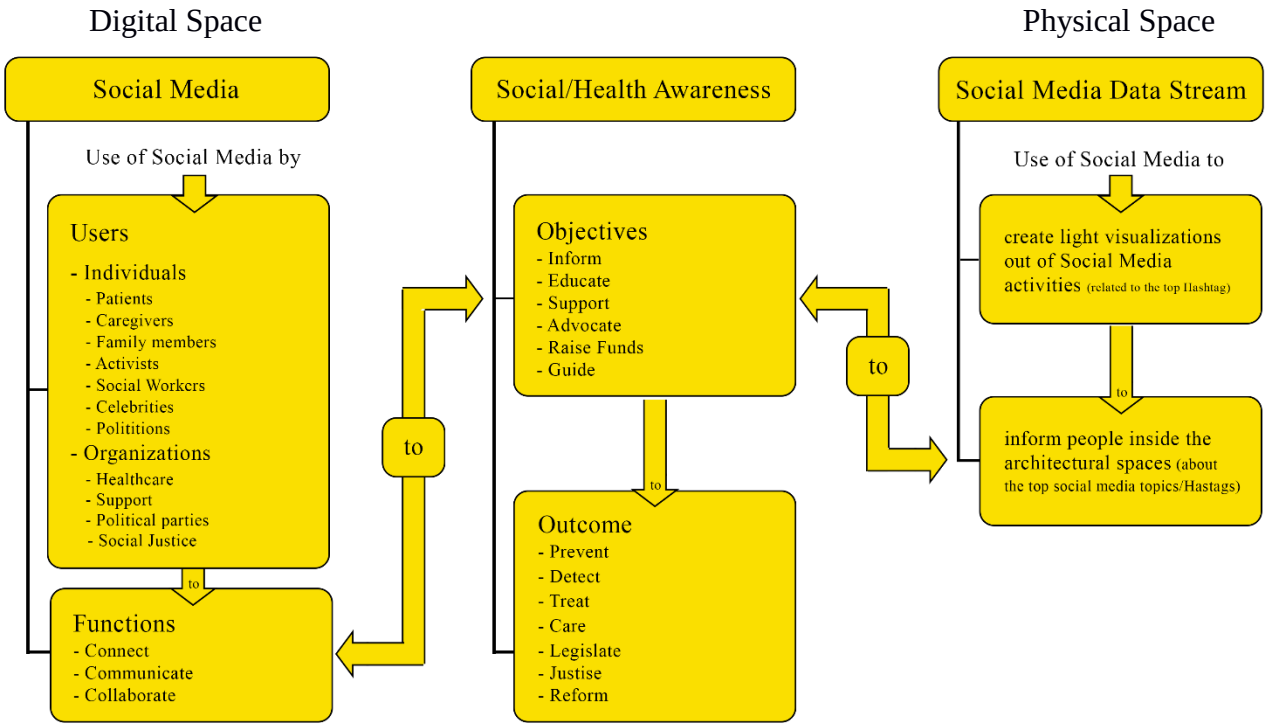


Fig.12: Diagram showing awareness increase through not only informing in social media, but also via light visualizations in the physical space.

In this study, we have identified several concerns about social media which are often mentioned by people who avoid it. For instance, there is a growing concern about the lack of reliability and quality of the disseminated information on the social media platforms when it comes to healthcare (physical, mental or social). Recent data breaches have demonstrated that lack of confidentiality and privacy concerns are no longer theoretical or improbable. Furthermore, anonymity or reduced accountability have increased the risks associated with communicating harmful or incorrect advice. Even if the information turns out to be factually correct, information overload has made it very difficult for the users to correctly apply the information found online to their own specific situation.

These are some of the reasons why some people choose to not participate in the social media movement or even actively try to avoid it. It can now be seen that just like many other technologies, the spread of social media platforms is accompanied with advantages as well as disadvantages. Despite its numerous downsides, there is no denying that social media can be used as an effective method of raising awareness. The question then becomes: how can we use this strength to our advantage while refraining from the parts of social media that are harmful?

In this paper, ambient light visualization was used to expose the social media activities relevant to the top social and health issues, in public spaces. The goal was to inform people in the physical world, some of whom do not participate in social media but who are eager to learn about different initiatives, about the most pressing issues. Thus, encouraging them to seek further information about such topics. To prevent the promotion of social media, the public displays of ambient light can be accompanied with additional links to resources that are determined to be of high quality. This is an important factor

as research has shown that part of the information that is disseminated on the social media platforms is of a lower quality compared to those generated by professionals.

Moreover, ambient light communication was used as the method for conveying this information. Understanding ambient light communication and the opportunities it can bring to human lives demonstrates that light has the potential to add a new layer to the environment, in a way that serves information and this information can be used for various applications. It was shown, that ambient light requires less cognitive effort from people and a produces a higher impact on their behavior. When compared to factual and graphical visualizations, ambient displays can reduce the amount of information mentally processed by providing an overview of the content by having information subtly portrayed in the periphery of one's attention; meaning that people can perform their primary tasks in the foreground while simultaneously receiving context information in the background of their attention. Furthermore, since ambient light is detectable by the periphery vision of human beings, it can help increasing awareness by grab the attention of more people. Conveying information in the peripheral field of vision.

To achieve our objectives, it was vital to show that the concepts of social media streams can be conveyed in an effective manner using ambient light visualization. To this end a set of light visualizations and social media data categories was identified and selected. An experiment was established to explore which data category the participants would perceive after watching each visualization. The results showed that most participants did indeed have a common perception of some of the data categories. This means that the participants shared a common understanding of these visualizations which suggests that in more general terms, light visualization can be used to form a very basic language to transfer information.

In conclusion, we showed that ambient light visualization integrated in public displays, can be used to raise awareness by informing people about the amount of attention towards a hot topic in social media in an unobtrusive way by displaying live data gathered from different activities such as number of shares, comments, and likes. Learning about top social and health issues can encourage people to seek further information about these causes. By providing access to relevant resources via links, QR codes, or other means, people can reach accurate information resulting in raising public awareness which hopefully would encourage them to act respectively (the process is demonstrated in fig.13).

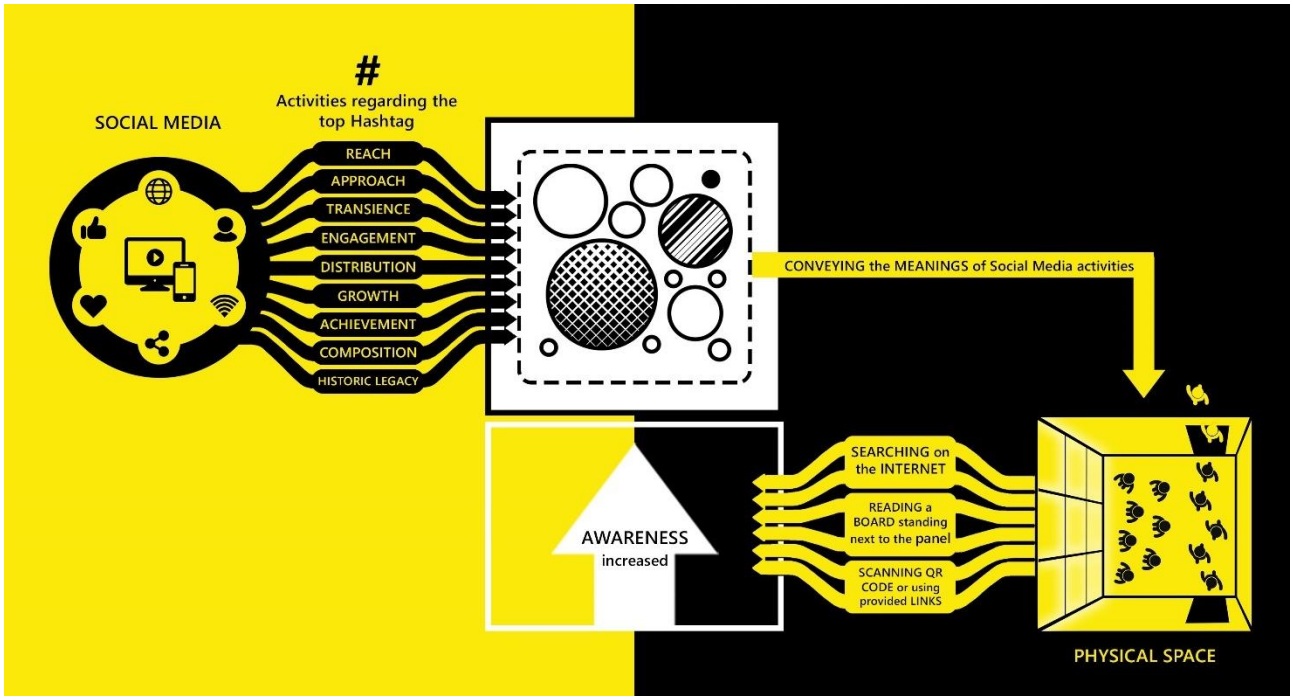


Fig.13: The journey of informing people inside physical world resulting in raising awareness.

You can find a short description of the project in the following video:

https://youtu.be/5yorUSjxRbg

And below you can find the text used in the video:

“

Social media have gained substantial popularity in recent years. And like many other technologies, the spread of social media platforms is accompanied with advantages and disadvantages. It should be our aim to avoid its pitfalls as much as possible and to exploit its benefits. One such advantage is the creation of a context for raising public awareness. These days awareness topics has increasingly been carried via the evolving medium of Hashtags. Hashtags, like me too, Climate Action, and Be Clear on Cancer. However, this information spread is limited to the digital world. Therefore, the opportunity to target people who are not the users of social media is neglected. There are some people who deliberately do not participate in social media but would be eager to know about different initiatives. The aim is not to encourage people to become part of the social media, but rather to use it as a computational engine to identify the most important social and health issues in order to raise awareness regarding these causes in the real world.

Ambient light visualization integrated in public displays, can be used to raise awareness by informing people about the amount of attention towards a hot topic in social media in an unobtrusive way by displaying live data gathered from different activities like the number of shares, comments, and likes. Learning about top social and health issues can encourage people to seek further information about these causes. By providing access to relevant resources via links, QR codes, or other means, people can reach accurate information resulting in raising public awareness which hopefully would encourage them to act respectively.

”

Chapter 5. Reflections and Recommendations

As it is expected, there were many choices that had to be made through out this project. In this chapter, we reflect on some of these choices and discuss their consequences and possible alternative approaches. It behooves us to start from one of the most fundamental decisions, using social media data streams for raising public awareness. To some people, recent social media seems like a negative technological development that must be avoided. Whether we are in favor of or opposed to the proliferation of social media, trends indicate that this technology is here to stay. Despite its numerous downsides, social media can be used a force to do good. When it comes to raising awareness in the physical world, visualizing social media data streams has a number of advantages over visualization of the factual information and trends about the cause itself.

We showed that visualizing social media activity data streams have several advantages over visualizing other available data streams related to social and health causes. For instance, social media data streams tend to be much more dynamic (changing in real-time) and would thus result in a more attractive and visually pleasing visualization compared to the slow to update data streams that are derived from the governmental or organizational websites. Furthermore, studies have shown that people tend to act with matching attitudes, beliefs, and behaviors to group norms. This can be used as a strong tool to encourage people to affect their behavior for the better.

Of course, care must be taken to avoid the pitfalls of social media as much as possible. As a source of purely factual information, social media is still far behind (in terms of quality) peer reviewed and professionally written articles and educational resources. It is the author's belief that people should not be triggered to seek such information from the social media networks. But rather, trigger them to critically think about various causes and encourage them to take appropriate action to seek high quality information about the topic. The method mentioned in this research was to provide access to these resources (via means of links, QR codes, etc.) near the ambient light installations. There may be other methods to achieve the same results.

Another major of the research was the experiment conducted to test if the concepts of social media activities can be conveyed using light visualizations. Even though, the tests show strong evidence that this is indeed possible, some parts of the tests were far from conclusive. It is the author's belief that further research into this matter is highly beneficial both for this project as well as other applications of ambient light communication. For instance, the interviews identified that color plays a vital role in every visualization. The impact and meaning of color are highly dependent on a wide variety of factors such as culture and context. Ambient displays that rely on color must select it with utmost care and after user tests.

Most prior research into ambient light communication, hinted that long duration exposure to these visualizations is required for good learning results. As with any other language, humans require time to learn this new visual language. To avoid this, the meaning of various social media data streams was thoroughly explained to the participants. In a real-life scenario, such an explanation is impossible or very hard to provide. Thus, the ambient light visualizations must be clear and simple enough that people can understand without a prior knowledge of its meaning. Furthermore, it is important to research of ability of people to learn such visual languages over an extended period of time.

Furthermore, the concepts explored in this research are quite simple and are only intended to demonstrate the potential of using social media activities for raising awareness. For improved effectiveness additional improvements can be made. For instance, by making the visualizations more context aware. This research proposed to visualize the top Hashtags across the entire range of social and health issues. However, depending on the context, these Hashtags can be filtered and only a

subset of them can be visualized. For instance, in a hospital, Hashtags related to healthcare issues can be visualized.

On a more personal note, planning was often one of the weak points of this project. This is one key area that should be improved for future endeavors. Furthermore, as is usually the case, communication was of utmost importance and was somewhat lacking. These issues lead to substantial delays in the publishing of the deliverables. All in all, this project was an incredible learning experience and provided a strong base for future research into the amazing field of lighting.

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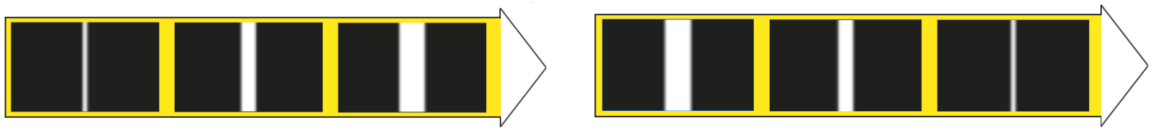
Appendices

Appendix A)

The final selection of the visual variables for creating the light visualizations for this test are as below: **Size**, **Lightness**, **Color**, **Location**, **Saturation**, **Focus**, **Moment**, **Frequency, Order, Rate of change**. From these variables, 9 visualizations were created. Here is the overview of the 9 pairs of visualization categories:

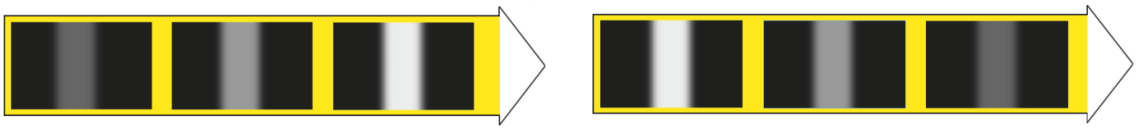
1) **Size**

This visualization plays with the **Size** variable.



2) **Intensity**

This visualization plays with the **Lightness** variable.

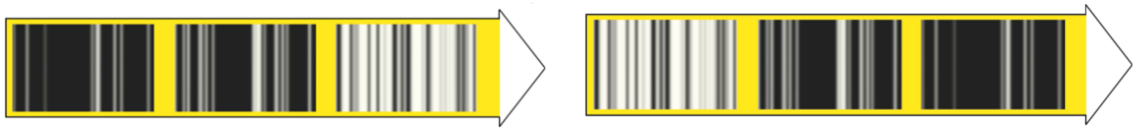


3) **Color**

This visualization plays with the **Color** variable.

4) **Aggregation**

This visualization is the most complex one. It plays with the **Location**, **Moment** and **Order** variables. Together, they become equivalent to texture for light.

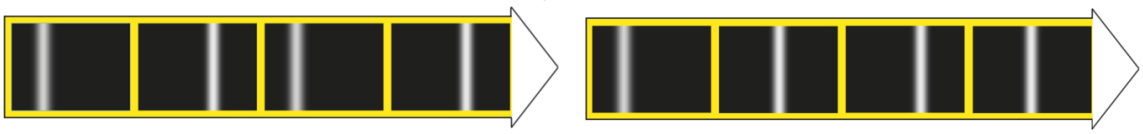


5) **Saturation**

This visualization plays with the **Saturation** variable.

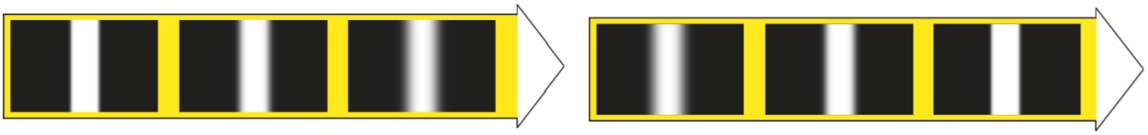
6) Rhythm

This visualization plays with the **Frequency** variable.



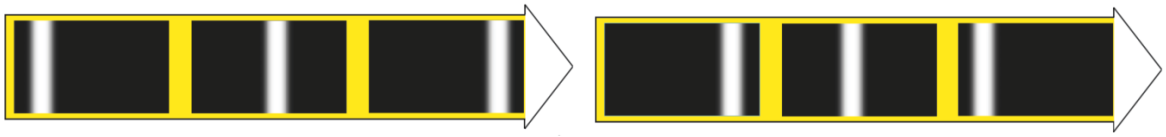
7) Blur

This visualization plays with the **Focus** variable.



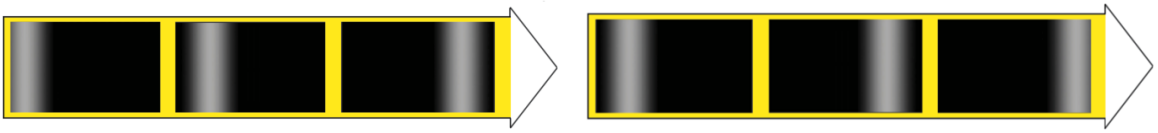
8) Direction

This visualization plays with the **Location** variables.



9) Acceleration

This visualization plays with the **Rate of change** variable.



Appendix C)

Visualizations vs. data categories

This part examines if each of the 18 visualization can be used as an effective method for conveying the meaning of one of the selected data categories. This is done by observing any outliers that fall outside of the normal distribution of the dependent variable. To achieve this, the dependent variable, representing the total number of times that the participants have selected a data category for a particular visualization (here after referred to as votes), is placed on the y-axis of the bar charts.
Similarly, the independent variable is represented by the 9 selected data categories and are labeled on the x-axis. It is important to note that the total number of votes for each data category is spread amongst the three data category trends (increase, decrease and constant). However, for this part of the analysis, the votes are all summed up to obtain the total number of times a particular data category has been selected by the participants for each visualization.
In the following 9 sub-sections, a pair of bar charts corresponding to a pair of converse visualizations is illustrated. Pairing matching visualizations may allow us to observe other interesting results which may have otherwise been missed. Moreover, the mean is used to quickly see if the number of votes for any of the data categories is above the average number of votes for that particular visualization and the median is also used as a more robust statistical average (against data sets that may contain extreme outliers). If we assume that the visualizations do indeed convey one or more data categories more successfully than the rest, outliers are expected, and the median will serve as a more accurate average. Other important elements on these bar charts are the highlighted segments that represent the 1 and 2 sigma (denoted as σ) boundaries.
In statistics, the standard deviation (SD, also represented by σ) is a measure that is used to quantify the amount of variation or dispersion of a set of data values [59]. A low standard deviation indicates that the data points tend to be close to the mean of the set, while a high standard deviation indicates that the data points are spread out over a wider range of values. In this study instead of expressing the variability of a population, the standard deviation is mostly used to measure confidence in statistical conclusions.
If it is assumed that the participants observe no correlation between the visualizations and the data categories (the null hypothesis), then distribution of the number of votes amongst the data categories will represent a normal Gaussian distribution according to the central limit theorem [60]. If one or multiple **data categories** receive significantly more votes than the average number of votes, standard deviation can be used as a tool to assess the likelihood that the result is insignificant or that the participants found a compelling reason to select (vote for) those particular **data categories**. As it can be seen in figure 9, if the number of votes for a particular **data category** is more than the mean value plus the standard deviation, there is a 15.9% probability that result is not caused by a correlation between the visualization and that data category. This is also referred to as passing the 1σ interval. If the number of votes passes the 2σ interval (is more than the mean value plus 2 times the standard deviation), that probability reduces to 2.3%.
Finally, the error bars that can be observed on top of the bar charts (representing the number of votes for each category), show the standard error (SE). The SE is determined by calculating the expected standard deviation in the results if the same test were to be conducted multiple times. This number is identical for all bars within a chart and is used as a tool to compare the number of votes between data categories for each visualization in order to determine if one is (statically) significantly better than the other. If the difference in the number of votes for two data categories (which are being compared), is within margin of error (the error bars overlap), then it cannot be assumed that the data category with a higher number of votes is necessarily better.

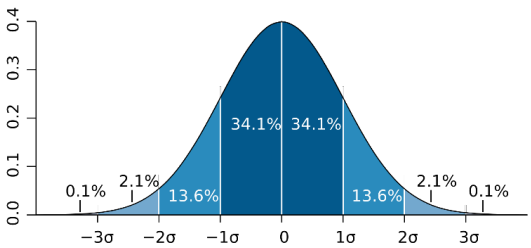
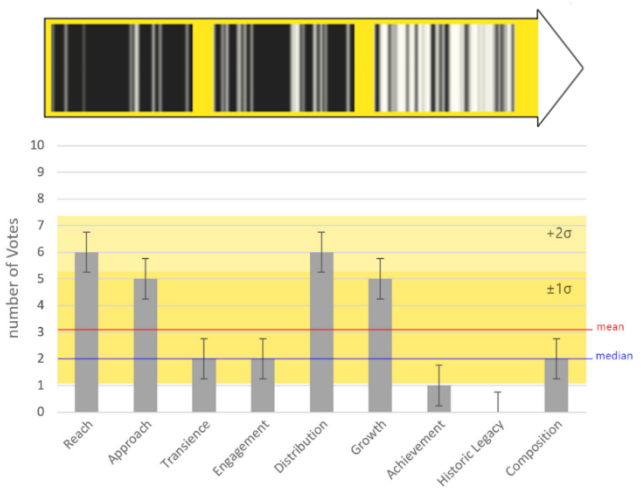


Fig.1

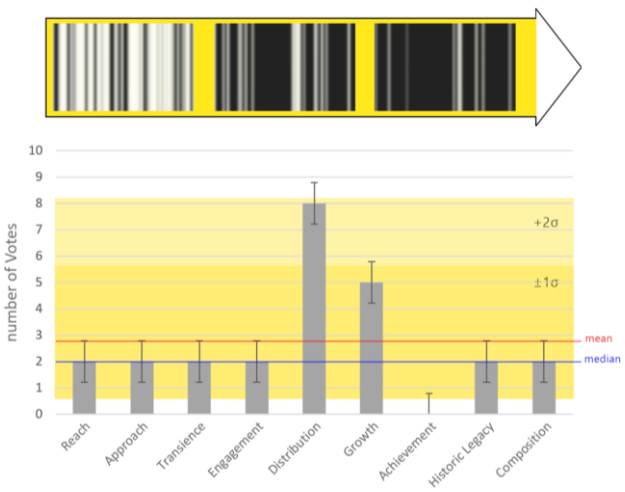
1) Aggregation

Normal



From the results, it can be observed that the data categories **Reach**, **Approach**, **Distribution** and **Growth** have received more votes than the mean and median values for this visualization. However, the number of votes for **Reach** and **Distribution** pass the 1σ making them slightly more suitable candidates to be used with this visualization. The error bars of all 4 aforementioned categories are overlapping however, meaning that no statistically significant difference exists between them. In summary, it can be concluded that this visualization is best suited to be used in first place to convey a meaning of **Reach** and **Distribution**, or secondly **Approach** and **Growth**.

Inverse



It can be observed that the only data categories with a total number of votes higher than the mean and median are **Distribution** and **Growth**. However, a quick glance at the chart shows that the clear winner and ideal candidate for this visualization is Distribution. The number of votes for this data category approaches the 2σ boundary and even when considering the measurement error, it is still far above the other data category **Growth**. Thus, according to the quantitative analysis, it can be concluded this visualization (Aggregation_Inverse) has a statically significant result and that it is best used to display **Distribution**.

Interview

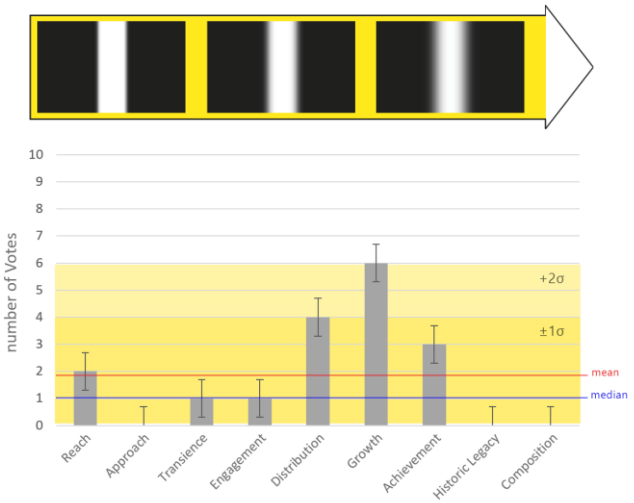
During the interviews, it was mentioned multiple times that the white lines were perceived as people/followers/viewers. Consequently, the change in the number of lines was also perceived as a change in number of viewers (**Distribution** and **Reach**) and followers (**Growth**). Moreover, 2 people mentioned that **Aggregation** was the easiest visualization to translate, giving an example of coordinating location to the line placement. Another interesting observation was that 3 of the participants mentioned that it was hard to distinguish white lines from black lines and whether the white is increase or conversely the black is decreasing.

Conclusions

To summarize, this pair of visualizations is a good candidate to be used for representing **Distribution** in later designs, since both the normal and inverse visualizations conveyed a meaning of increase/decrease in Distribution. Furthermore, when considering the qualitative analysis, **Growth** and possibly **Reach** may present other alternatives. Due to the explanation of the meaning of **Reach** (the number of times a post has been exposed to the users), this data category can only increase therefore can be represented through the first visualization (Aggregation_Normal).

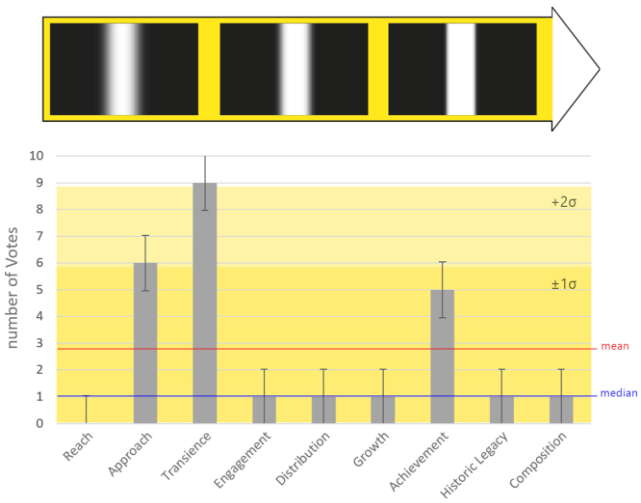
2) Blur

Normal



From the results, it can be observed that the data categories **Reach**, **Distribution, Growth** and **achievement** have received more votes than the mean and median values for this visualization. However, the number of votes for **Distribution** and **Growth** pass the 1σ and 2σ boundaries making them more suitable candidates to be used with this visualization. When considering the margin of error (as shown by the error bars), one can conclude that **Growth** is ultimately the best data category to be used with this visualization.

Inverse



It can be observed that the only data categories with a total number of votes higher than the mean and median are **Approach, Transience** and **Achievement**. Out of these data categories however, the number of votes for **Approach** and **Transience** reach a statically significant amount. A quick glance at the chart shows that the clear winner and ideal candidate for this visualization is Transience. The number of votes for this data category approaches the 2σ boundary and the even when considering the measurement error, it's still far above the other data category **Approach**. Thus, according to the quantitative analysis, it can be concluded this visualization has a statically significant result and that it is best used to display **Transience**.

Interview

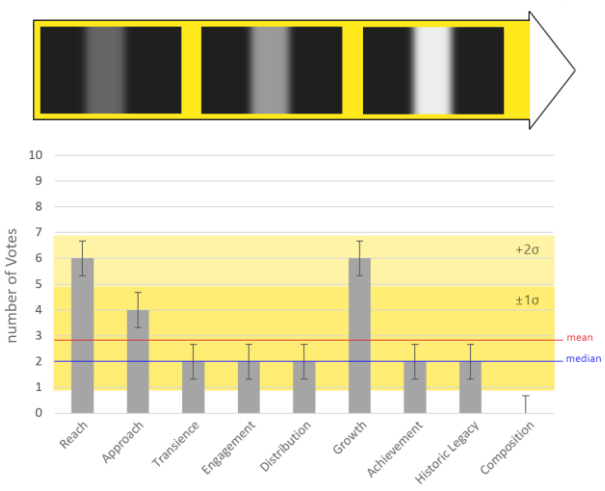
During the interviews, most of the participants stated that they perceived a decrease in blur as approaching an object. As one gets closer, the object becomes more apparent and clearer. Other participants related the decrease in blurriness as the passage of time or the content (image or video) loading. As time passes one gets closer to seeing what they wanted. Lastly, no particular data category trend was observed by the participants.

Conclusions

Unfortunately, this pair of visualizations do not share any common data categories. This means that even though each visualization by itself may be used to convey **Growth** or **Transience**, it is not very wise to use this pair to convey and increase or decrease in any of the data categories. The qualitative analysis also confirms the quantitative analysis (i.e. participants cannot associate these visualizations with an increase or decrease). Blue_Inverse can however be employed by itself for conveying Transience (for instance approaching the end of something).

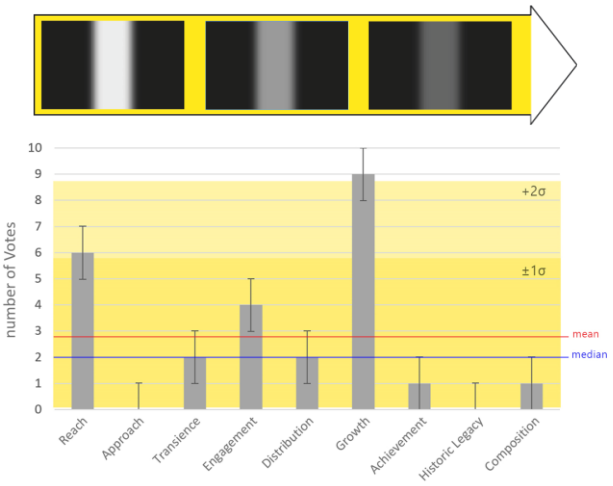
3) Intensity

Normal



From the results, it can be observed that the data categories **Reach**, **Approach** and **Growth** have received more votes than the mean and median values for this visualization. However, the number of votes for **Reach** and **Growth** pass the 1σ boundary making them more suitable candidates to be used with this visualization. Moreover, the 2 aforementioned categories have received the exact same number of votes, meaning that no other conclusions can be drawn to distinguish the leading candidate amongst them. In summary, it can be concluded that this visualization is best suited to be used to convey a meaning of **Reach** and **Growth**.

Inverse



It can be observed that the only data categories with a total number of votes higher than the mean and median are **Reach, Engagement** and **Growth**. Out of these data categories however, the number of votes for **Reach** and **Growth** reach a statically significant amount. The number of votes for these two data categories passes the 1σ and 2σ boundaries making them more suitable candidates to be used with this visualization. With more than 3 votes as compared to **Reach**, the chart shows that the clear winner and ideal candidate for this visualization is **Growth**. This remains true even when considering the measurement error. Thus, according to the quantitative analysis, it can be concluded this visualization has a statically significant result and that it is best used to display **Growth**.

Interview

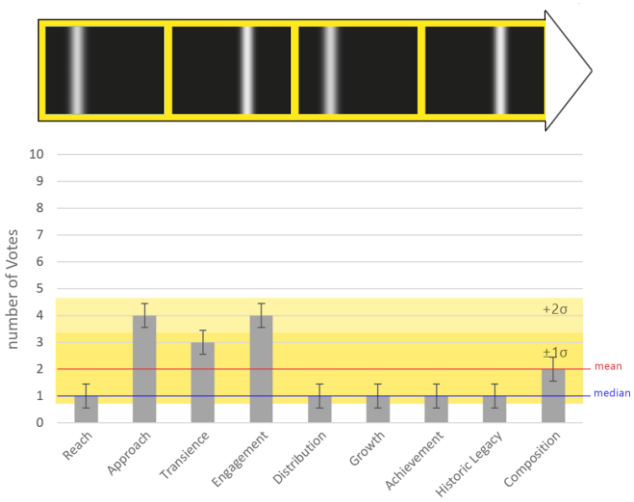
Similar to the "Aggregation", perceived the increase or decrease in intensity as the number of viewers or followers changing. Thus, they associated this visualization with Reach and Growth. Others attributed a decrease in intensity, as a post disappearing as it loses interest over time. This a decrease in brightness tends to convey a feeling of passage of time and being forgotten.

Conclusions

The results show that this pair of visualizations is an ideal candidate to convey **Growth**. The converse pair also performs very well when conveying a sense of increase or decrease leaving little ambiguity when it comes to these two visualizations.

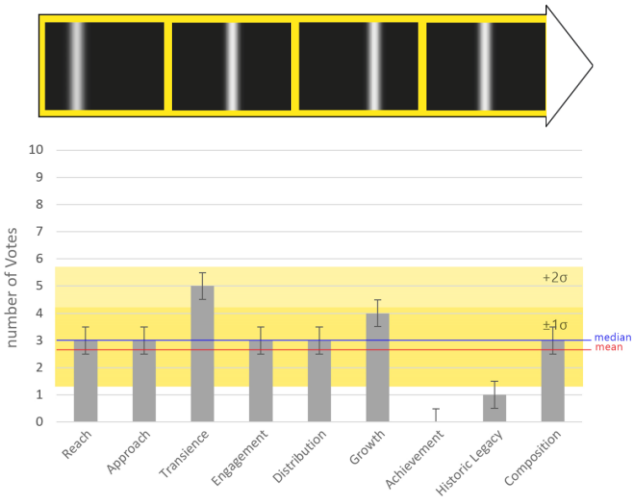
4) Rhythm

Normal



From the results, it can be observed that the data categories **Approach**, **Transience** and **Engagement** have received more votes than the mean and median values for this visualization. However, the number of votes for **Approach** and **Engagement** pass the 1σ boundary making them more suitable candidates to be used with this visualization. Moreover, the 2 aforementioned categories have

Inverse



It can be observed that the only data categories with a total number of votes higher than the mean and median are **Transience** and **Growth**. Out of these data categories however, the number of votes for **Transience** reaches a statically significant amount. The number of votes for this data category passes the 1σ boundary making it a more suitable candidates to be used with this visualization. This remains true even when considering the measurement error. Thus, according to the quantitative analysis, it can be concluded this visualization (Rhythm_Regular) is best used to display **Transience**.

Interview

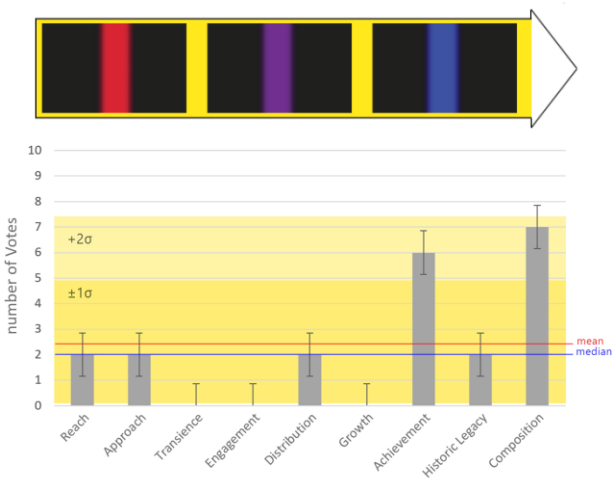
A number of interesting observations resulted from the interviews. Some participants perceived the back and forth motion of the line as scrolling or flipping through pages of a book. Others related the irregular motion of the line to a conversation between two persons and described it as engagement. Last but not the least, cultural differences seem to be boldened for this particular visualization. Several Indian participants perceived the regular left/right motion as “no” as it resembles a person shaking their head to show disapproval. Other European participants perceived this motion as something akin to dancing and thus viewed it in a positive light. With regards to observing a trend in the data category (increase/decrease), most participants could not sense such a trend and were motivated to select “constant”.

Conclusions

Unfortunately, this pair of visualizations do not share any common data categories. This means that even though each visualization by itself may be used to convey **Engagement** or **Transience**, it is not very wise to use this pair to convey and increase or decrease in any of the data categories. The qualitative analysis also confirms the quantitative analysis (i.e. participants cannot associate these visualizations with an increase or decrease) or even a common data category.

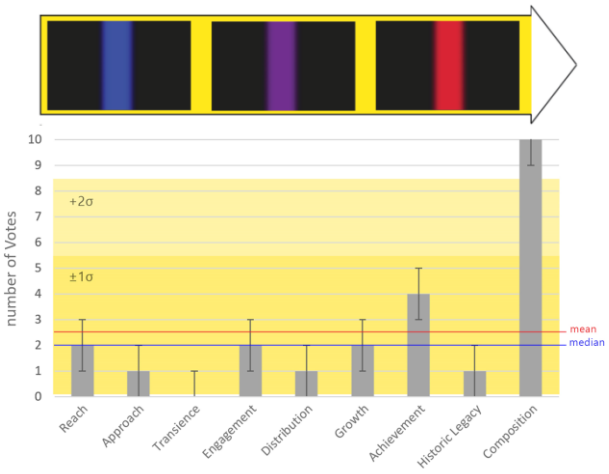
5) Color

Normal



From the results, it can be observed that the data categories **Achievement** and **Composition** have received more votes than the mean and median values for this visualization. The number of votes for both categories pass the 1σ boundary making the results statistically significant. Due to the margin of error as shown by the error bars, it is impossible to narrow than this selection to a single category. As such, it can be concluded that this visualization is best suited to be used to convey both **Achievement** and **Composition**.

Inverse



It can be observed that the only data categories with a total number of votes higher than the mean and median are **Achievement** and **Composition**. Out of these data categories however, the number of votes for **Composition** reaches and surpasses a statically significant amount (the 2σ boundary). Thus, it can be confidently concluded that according to the quantitative results, this visualization is best used to display **Composition**.

Interview

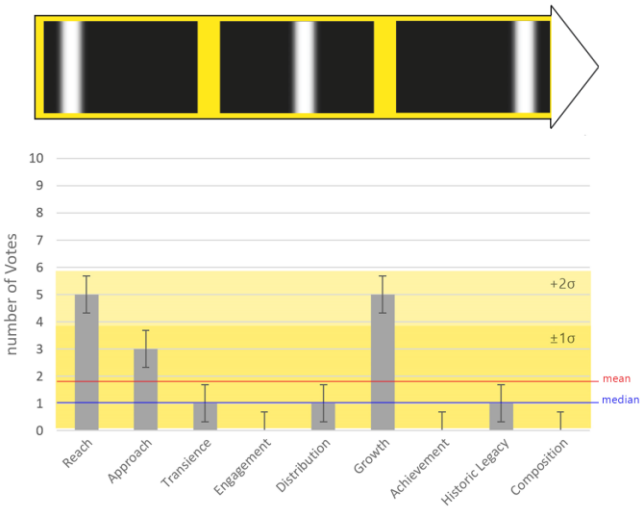
The most noticeable comments received from the participants were with regards to allocating meanings to different colors. For instance, a number of participants translated color to gender (they identified blue as male and red as female). One participant mentioned that colors can be assigned to different social medias; for instance, blue for Facebook or Pink/Purple for Instagram. Overall, it can be concluded that most people do not have any a priory understanding of colors and that these associations are made over the time through visual clues. Moreover, it is important to consider the feeling that some colors may convey. For instance, some participants associate red with a negative feeling. But more commonly, participants translated the transformation from a cool color to warm as something positive. Finally, the majority of participants did not perceive a trend (increase/decrease) for this pair of visualizations.

Conclusions

To summarize, this pair of visualizations is a good candidate to be used for representing **Composition** in later designs. However, nothing can be concluded regarding the trend of the data category. Most people perceive cannot associate a change in color to an increase or decrease. This fact is quite intuitive when considering the fact that composition is defined as a ratio of constituents where the total is always constant.

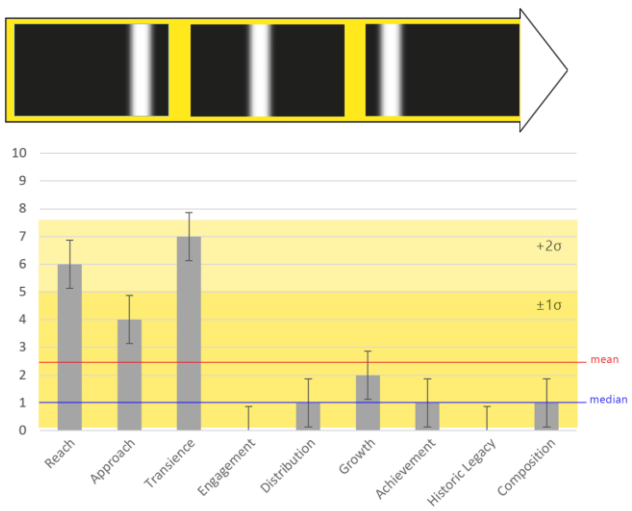
6) Direction

Normal



From the results, it can be observed that the data categories **Reach, Approach** and **Growth** have received more votes than the mean and median values for this visualization. However, the number of votes for **Reach** and **Growth** pass the 1σ boundary making them more suitable candidates to be used with this visualization. Moreover, the 2 aforementioned categories have received the exact same number of votes, meaning that no other conclusions can be drawn to distinguish the leading candidate amongst them. In summary, it can be concluded that this visualization is best suited to be used to convey a meaning of **Reach** and **Growth**.

Inverse



It can be observed that the only data categories with a total number of votes higher than the mean and median are **Reach, Approach** and **Transience**. Out of these data categories however, the number of votes for **Reach** and **Transience** reaches and surpasses the 1σ boundary. However, given the margin of error, no further conclusions can be drawn and both data categories remain equally suitable to be used with this visualization.

Interview

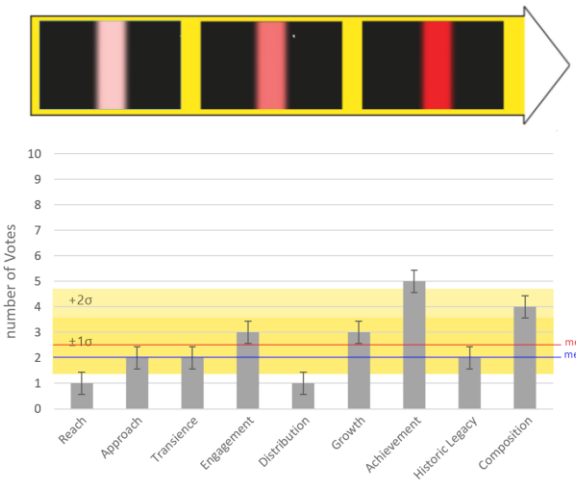
Some interesting insights were obtained from the interviews with regards to this pair of visualizations. A large number of participants perceived the left to right motion as forward progress (for instance a video playing and the progress bar moving to the right). Therefor **Transience** was the most popular option for this particular visualization. With regards to the perception of a trend in the data category, the results were mixed. Participants that natively used left to right languages (such as Europeans), perceived a right to left motion as inverted and associated it to a decrease (going backwards). Other participants observed did not make this association.

Conclusions

To summarize, **Reach** is the only common data category that can be conveyed using this pair of visualizations. The qualitative analysis also shows that given a similar target group (with regards to the native language they use) a sense of trend (increase/decrease) can also be reliably conveyed.

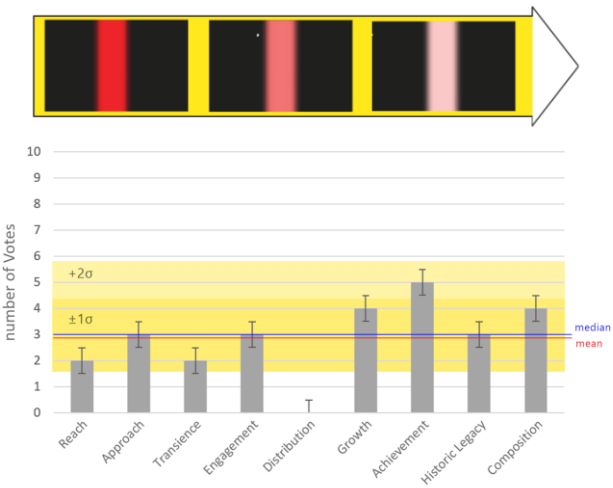
7) Saturation

Normal



From the results, it can be observed that the data categories **Engagement, Growth, Achievement** and **Composition** have received more votes than the mean and median values for this visualization. However, the number of votes for **Achievement** and **Composition** pass the 1σ boundary making them more suitable candidates to be used with this visualization. Due to the margin of error, no other conclusions can be drawn to distinguish the leading candidate amongst these two categories. In summary, it can be concluded that this visualization is best suited to be used to convey a meaning of **Achievement** and **Composition**.

Inverse



It can be observed that the only data categories with a total number of votes higher than the mean and median are **Growth, Achievement** and **Composition**. Out of these data categories however, the number of votes for **Achievement** reaches and surpasses the 1σ boundary proving to be a slightly better candidate. However, given the margin of error, no further concrete conclusions can be drawn and both data categories could be suitable to be used with this visualization.

Interview

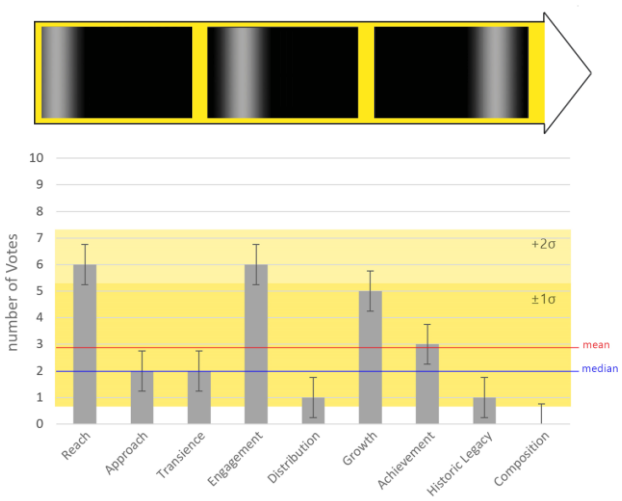
Participants had two opposing views with regards to this pair of visualizations. Some of them commented that a transition from colorless to a saturated color is positive and therefore they could relate to an achievement. On the other hand, some of the participants found this transition to be negative, since the red color is becoming more prominent and in their point of view red is associated with something bad or wrong. Similarly, the second group perceived the converse visualization (from a saturated red to colorless) as an achievement because the red is becoming less dominant until it loses all of its color therefore showing a positive progress. This highlight the importance of choosing the color while using saturation as a tool.

Conclusions

To summarize, adding the insights gained from the qualitative analysis as well as the results from the quantitative one, **Achievement** is the leading candidate to be conveyed using this pair of visualizations. **Composition** is another alternative data category that may be used successfully.

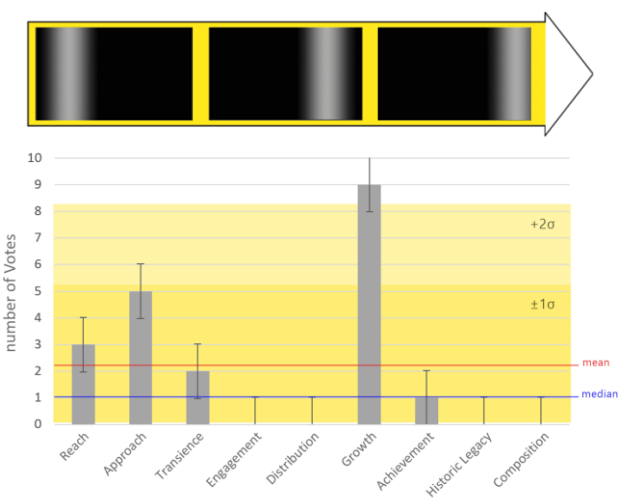
8) Acceleration

Normal



From the results, it can be observed that the data categories **Reach, Engagement, Growth** and **Achievement** have received more votes than the mean and median values for this visualization. However, the number of votes for **Reach** and **Engagement** pass the 1σ boundary making them more suitable candidates to be used with this visualization. Due to the margin of error, no other conclusions can be drawn to distinguish the leading candidate amongst these two categories. In summary, it can be concluded that this visualization is best suited to be used to convey a meaning of **Reach** and **Engagement**.

Inverse



It can be observed that the only data categories with a total number of votes higher than the mean and median are **Reach, Approach** and **Growth**. Out of these data categories however, the number of votes for **Growth** stands far above the other 2 categories and even surpasses the 2σ boundary. Thus, it can be confidently concluded that according to the quantitative results, this visualization is best used to display **Growth**.

Interview

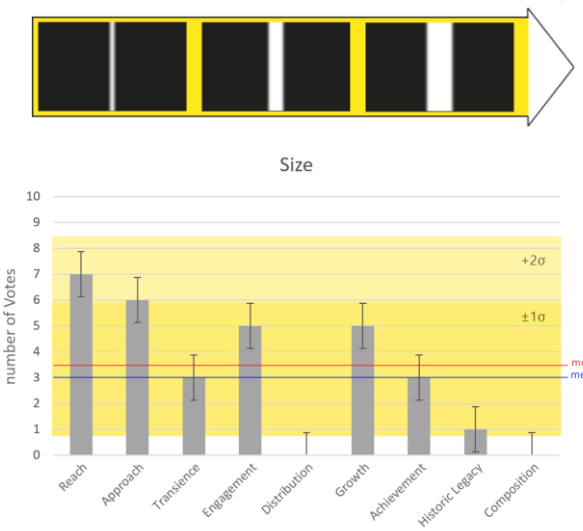
During this interview an interesting theme became apparent. Participants show a great tendency to perceive Growth from any visualization that conveys a strong data trend (increase/decrease). The increase and decrease in speed were almost universally seen as increase and decrease in **Growth**. There were a couple of participants who still felt that the left to right movement is dominant, so they preferred to choose “increase” for a decelerating motion. It is also important to mention that many participants perceived such movements as the passage of time.

Conclusions

Unfortunately, this pair of visualizations do not share any common data categories. This means that even though the two visualizations by themselves may be used to convey **Reach/Engagement** or **Growth**, it is not very wise to use this pair to convey and increase or decrease in any of the data categories. The qualitative analysis (combined with the quantitative results) suggest that **Growth** can be conveyed somewhat successfully with this visualization, but further research is required.

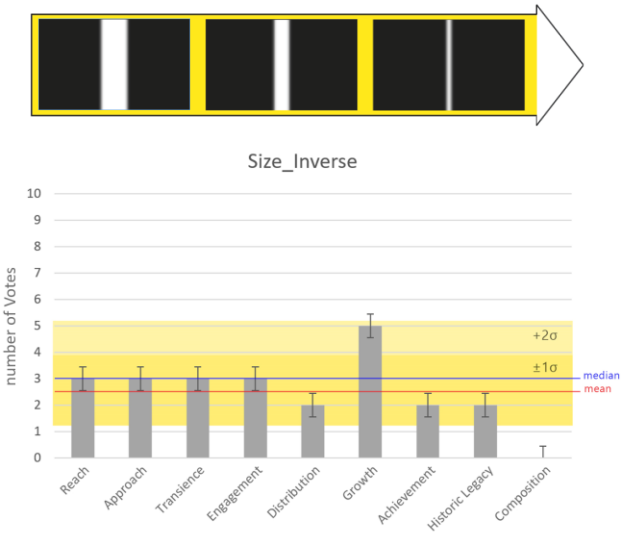
9) Size

Normal



From the results, it can be observed that the data categories **Reach, Approach, Engagement** and **Growth** have received more votes than the mean and median values for this visualization. However, the number of votes for **Reach** and **Approach** pass the 1σ boundary making them more suitable candidates to be used with this visualization. Due to the margin of error, no other conclusions can be drawn to distinguish the leading candidate amongst these two categories. In summary, it can be concluded that this visualization is best suited to be used to convey a meaning of **Reach** and **Approach**.

Inverse



It can be observed that the only data category with a total number of votes higher than the mean and median is **Growth**. Furthermore, the number of votes for **Growth** stands far above the other categories and approaches the 2σ boundary. Thus, it can be concluded that according to the quantitative results, this visualization is best used to display **Growth**.

Interview

A noticeable observation was that the participants had an associated a change in size to a very wide range of meanings (for instance change in the number of views/followers or likes/comments, etc.). Interestingly, some participants commented that a growing light that starts from the middle is similar to opening a door, thus they perceived it as **Reach** and **Approach**. And with the opposite description, they mentioned that this door closure can represent something which is getting forgotten, losing interest, or coming to an end.

Conclusions

Unfortunately, this pair of visualizations do not share any common data categories. This means that even though the two visualizations by themselves may be used to convey **Reach/Approach** or **Growth**, it is not very wise to use this pair to present any of the data categories. The qualitative analysis (combined with the quantitative results) suggest that these visualizations are excellent for conveying a trend (increase/decrease) however.

Visualizations vs data category trends

The distribution of the votes between the data category trends is the subject of the second part of the analysis. In this section, the possibility of using the 18 selected visualizations, as a means of conveying a sense of increase, decrease or constancy (here after referred to as data category trend) is examined. As such the total number of votes for each data category trend (this means across all data categories) is summed up for each of the 18 visualizations and plotted on the y-axis of the 3 bar charts that represent increase, decrease and constancy. Similarly, the independent variable is represented by the aforementioned 18 visualizations and are labeled on the x-axis.

In the following sub-sections, a pair of bar charts corresponding to the increase/decrease data category trends are illustrated. Pairing these charts will allow us to observe if converse visualizations do indeed convey a converse trend to the participants. The mean and median values of the number of votes across all data categories is illustrated as a blue and red line, respectively. The mean is used to quickly see if the number of votes for any of the data category trends is above the average number of votes for all visualizations. The median is also used as a more robust statistical average (against data sets that may contain extreme outliers). If we assume that the some of the selected visualizations are indeed able to convey one of the data category trends more successfully than the rest, outliers are expected, and the median will serve as a more accurate average. Other important elements on these bar charts are the highlighted segments that represent the 1 sigma (denoted as σ) boundary.

Increase/Decrease

The key in finding a good visualization for conveying a sense of increase or decrease is to find a pair of converse visualizations that show an inversely proportional relationship when we observe its number of votes in figure 2 and 3. To clarify, this means that whenever a visualization receives a high number of votes for increase, it's converse visualization should receive a low number of votes. Similarly, when looking at the number of votes for decrease, this pair of visualization should present the opposite results. Any pairs of visualizations that this illustrate behavior is an ideal candidate to convey increase and decrease in a reliable manner.

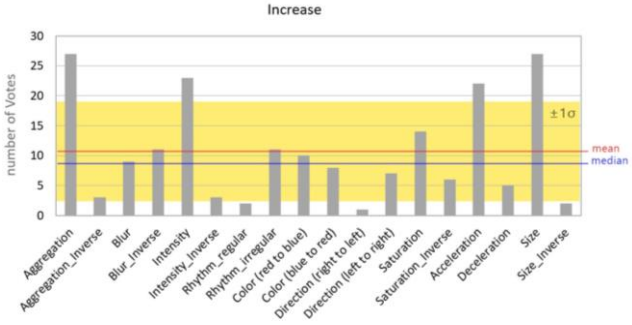


Fig 2.

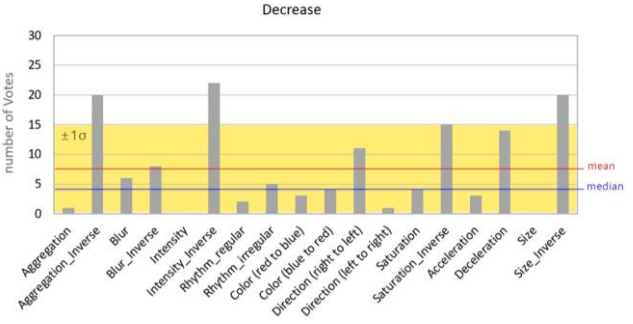


Fig 3.

When looking at the first bar chart (illustrating the number of votes for the increase), it can be observed that the following visualizations received more votes than the mean and median value: **Aggregation, Blur (inverse), Intensity, Rhythm (irregular), Saturation, Acceleration** and **Size**. Out of these visualizations, the number of votes for **Aggregation, Intensity, Acceleration** and **Size** pass the 1σ boundary and thus show a statically significant result. Furthermore, their converse visualization has a number of votes that are far below the mean and median. These four visualizations are excellent candidates to convey a sense of increase.
On the other hand, figure 3 illustrates that, **Aggregation (inverse), Blur (inverse), Intensity (inverse), Direction (left to right), Saturation (inverse), Deceleration** and **Size (inverse)** have received more votes than the mean and median values. Out of these visualizations, **Aggregation (inverse), Intensity (inverse), Saturation (inverse)** and **Size (inverse)** show statistically significant results by

obtaining enough votes to pass the 1σ threshold. Moreover, their converse visualizations have received less votes than the mean and median value of votes.
Comparing the above 2 sets of visualizations side by side, it can be observed that **Aggregation, Intensity** and **Size** are form pairs of visualizations that indeed display the all of the requirements to be used as a method to convey a sense of increase and decrease reliably. Though not as statically significant, the results hint that **Saturation** and **Acceleration** can also be used successful for this purpose. As mentioned before, interviews show that the color used to display **Saturation** and the direction of motion for **Acceleration** play an important role in how they are perceived. Further research is advisable to draw more concrete conclusions with regards to the suitability of these two visualizations.

Constant

If one needs to convey the meaning of one the selected data categories without an associated sense of increase or decrease, which visualization is suitable? This section aims to answer this question. From figure 4, it can be observed that the following visualizations received more votes than the mean and median value: **Blur (inverse), Rhythm (regular), Rhythm (irregular), Color (red to blue), Color (blue to red) and Direction (left to right)**. With the exception of **Blur** and **Direction**, the other 4 visualizations form a pair (**Rhythm**, **Color**), meaning that both the normal as well as the converse visualizations don't seem to convey any sense of increase or decrease. These visualizations can be used with other visualization to provide additional information without affecting the overall sense of trend.

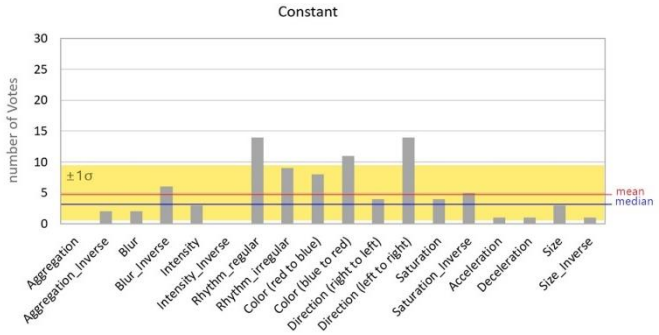


Fig 4.

Conclusions

In this section, all the knowledge gathered from the quantitative as well as qualitative analysis of the results is combined in order to see if the objectives of this test have been accomplished. As a reminder, this experiment was established and performed to conclude if the selected data categories can be conveyed using any of the prepared visualizations. The results showed that most participants did indeed have a common perception of some of the data categories. This means that the participants shared a common understanding of these visualizations which suggests that in more general terms, light visualization can be used to form a very basic language to transfer information.

The results for some of the data categories were more concrete than others. For instance, Distribution, Growth and Composition are best displayed using Aggregation, Intensity and Color, respectively. Achievement can be conveyed by using Saturation provided more that an appropriate color is selected. This of course is a good subject for further study. Furthermore, Transience can be displayed successfully by Rhythm if there is no need to also convey a trend in this data category. The results also showed that a pair of converse visualization may be used for conveying 2 different data categories. For instance, Acceleration and Deceleration can display Engagement and Growth, respectively. This knowledge can be applied in more specific cases by designers.

Lastly, it was also shown that data trends (increase/decrease) are best expressed using Aggregation, Intensity and Size, and that people tend to get a sense of constancy from a shifting color or regular/irregular movements. This experiment does not fill every gap in our current understanding of the subject. In contrary, a lot more research is required in this area to be able to define the building blocks for this new language. However, the results of the experiment should provide a solid foundation for future researchers.