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Joyful infographics: added educational value?

Exploring the impact of emotion-driven design strategies on learning

A Master Thesis by Anna-Louisa Dogley

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Abstract

This thesis examines the impact of emotion-driven strategies on multimedia learning among highly educated individuals. Three of Nigel Holmes' criteria for creating joyful infographics- drawings, visual prosody and human presence- are tested for their ability to support learning. Through a comparative study in the form of online surveys, the thesis investigates and measures the difference in retention and transfer performances between participants from treatment and control groups. The results show that the three features positively impacted transfer performances but had no observable impact on retention performances. Other observations included that the presence of faces itself directly and positively impacted transfer performances. A positive but indirect impact was also noticeable from the combination of the three features as they encouraged engagement with information beyond the infographic's visual aid but with the text information provided by the infographic.

Keywords: emotional design, cognitive theory of multimedia learning, infographics, comparative study, seductive detail

Declaration of work

I, _____, confirm that the work for the

following paper with the title:"_____"

was solely undertaken by myself, and no assistance was provided from other sources as those allowed. All sections of the paper that use quotes or describe an argument or concepts developed by another author have been referenced, including all secondary literature used to show that this material has been adopted to support my thesis.

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Content

1. Introduction

Around the turn of the millennium, infographics gained popularity as a trendy method of presenting educational content in a visual format.[1,2] Infographics, however, have their roots in millennia-long practices of humans communicating information through images. Informational art can be observed in early cave paintings, emblem books of the middle ages or more recent cartographic, astronomic, architectural and scientific visualisations.[3] Today, the relevance of information visualisation continues to persist across various fields, such as journalism, science, politics and design.[4,5] This diverse application of information visualisation has resulted in the emergence of multiple design approaches and sparked debates on the most effective and suitable ways to produce informative and engaging infographics.[6] This thesis highlights one of the many suggested practices by investigating the impact of emotional design in infographics.

In the past 30 years, neuroscience scholars have studied the relationship between emotion and cognition and considered them to be intricately linked.[7,8,9] This finding then led to a paradigm shift because up till then, cognition and emotion were historically seen as separate human functions in different brain areas.[10] Cognitive processes were perceived as more sophisticated, whereas emotion was considered a "primitive" human function.[11,12] The exclusion of emotion in understanding cognitive

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[1]Traboco, Lisa et al. "Designing Infographics: Visual Representations for Enhancing Education, Communication, and Scientific Research." *Journal of Korean medical science,* vol. 37,27 e214. 11 Jul. 2022, doi:10.3346/jkms.2022.37.e214.

[2] Rendgen, Sandra. "Introduction." *Information graphics*, edited by Julius Wiedemann, Taschen, 2020, pp. 7–36, pp 9.

[3] Amit-Danhi, Eedan R. & Shifman, Limor. "Digital Political Infographics: A Rhetorical Palette of an Emergent Genre." *New Media & Society*, vol. 20, no. 10, SAGE Publishing, Jan. 2018, pp. 3540–59, doi:10.1177/1461444817750565, pp. 3540.

[4] Rendgen, Introduction, pp. 9.

[5] Amit-Danhi & Shifman. Digital political infographics, pp. 3540.

[6] Dick, Murray. *The Infographic: A History of Data Graphics in News and Communications*. MIT Press, 2020, pp 17.

[7] Dolan, R J. "Emotion, cognition, and behavior." *Science*, vol. 298, 2002, pp. 1191-4. doi:10.1126/science.1076358, pp. 119.

[8] Phelps, Elizabeth A. "Emotion and cognition: insights from studies of the human amygdala." *Annual review of psychology*, vol. 57, 2006, pp. 27-53. doi:10.1146/annurev.psych.56.091103.070234. pp. 27.

[9] Izard, Carroll E. "Emotion Theory and Research: Highlights, Unanswered Questions, and Emerging Issues." *Annual Review of Psychology*, vol. 60, no. 1, Jan. 2009, pp. 1–25, doi:10.1146/annurev.psych.60.110707.163539, pp.1.

[10] Pessoa, Luiz. "On The Relationship Between Emotion and Cognition." *Nature Reviews Neuroscience*, vol. 9, no. 2, Nature Portfolio, Feb. 2008, pp. 148–58, doi:10.1038/nrn2317, pp. 148.

[11] Pessoa, Relationship, pp. 148.

[12] Norman, Donald A. *Emotional design: why we love (or hate) everyday things*, Basic Books, 2004, pp. 18.

processes could also be observed in multimedia learning theories such as Sweller's *Cognitive Load Theory* and Mayer's *Cognitive Theory of Multimedia Learning*. It was not until Moreno and Mayer's revision of the *Cognitive Theory of Multimedia Learning* and reframing it into the *Cognitive-Affective Theory of Learning with Media* that emotion was included in the science multimedia learning.[13,14] More recently, there has been an increase in studies on emotional design in multimedia.[15] The results have been promising, as emotional design has proven to be positively impactful to learning outcomes in several instances.[16,17] This paper continues this line of research and targets it from the perspective of Nigel Holmes' *"Joyful Infographics: A friendly, human approach to Data".*[18] Specifically, three of his nine criteria for creating joyful infographics, which include adding humans, hand-drawn drawings and visual prosody, are investigated in terms of their impact on learning. Holmes speculates that even scientists, as infographic readers, may benefit from infographics created *joyfully*.[19] A claim that challenges the *expertise reversal effect*, whereby it is argued that techniques that may be optimal for novices may hinder the performance of experienced learners.[20,21] This thesis conducts a comparative analysis through surveys within the framework of multiple multimedia learning theories, such as the aforementioned *Cognitive Theory of Multimedia Learning* and the *expertise reversal effect*. With survey participants split into either the treatment or control group, the study examines the impact of Holmes' criteria on highly educated viewers.

The paper is structured into seven chapters. In chapter two, the motivation behind the study is presented. The chapter outlines Nigel Holmes' criteria for creating joyful

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[13] Moreno, Roxana. "Cognitive Load Theory: More Food for Thought." *Instructional Science*, vol. 38, no. 2, *Springer Science+Business Media*, Nov. 2009, pp. 135–41, doi:10.1007/s11251-009-9122-9. pp. 137.
[14] Plass, Jan L. & Kaplan, Ulas. "Emotional Design in Digital Media for Learning." *Emotions, Technology, Design, and Learning*, edited by Sharon Y. Tettegah & Martin Gartmeier, Elsevier, 2016, pp. 131–161, doi:10.1016/b978-0-12-801856-9.00007-4, pp 131.
[15] Mayer, Richard E. *Multimedia learning*. 3rd ed., Cambridge University Press, 2021, pp.73.
[16] Brom, Cyril et al. "How Effective Is Emotional Design? A Meta-analysis on Facial Anthropomorphisms and Pleasant Colors During Multimedia Learning." *Educational Research Review*, vol. 25, Elsevier, Nov. 2018, pp. 100–19, doi:10.1016/j.edurev.2018.09.004, pp. 100.
[17] Wong, Rachel O. L. & Olusola Adesope. "Meta-Analysis of Emotional Designs in Multimedia Learning: A Replication and Extension Study." *Educational Psychology Review*, vol. 33, no. 2, Springer Science+ Business Media, July 2020, pp. 357–85, doi:10.1007/s10648-020-09545-x, pp. 357.
[18] Holmes, Nigel. *Joyful Infographics: A friendly, human approach to data*. CRC Press, 2023.
[19] Holmes, *Joyful Infographics*, pp. 43.
[20] Kalyuga, Slava. "Effects of Learner Prior Knowledge and Working Memory Limitations on Multimedia Learning." *Procedia - Social and Behavioral Sciences*, vol. 83, Elsevier BV, July 2013, pp. 25–29, doi:10.1016/j.sbspro.2013.06.005, pp. 26.
[21] Kalyuga, Slava. "Expertise Reversal Effect and Its Implications for Learner-Tailored Instruction." *Educational Psychology Review*, vol. 19, no. 4, *Springer Science+Business Media*, Sept. 2007, pp. 509–39, doi:10.1007/s10648-007-9054-3, pp. 509.

infographics and delves into the discussion between him and Edward Tufte regarding their differing approaches. Chapter three introduces the study's theoretical framework. Here, the approach taken is clarified by outlining the definitions and theories considered during the research. Furthermore, the chapter elaborates on the multiple theories and research findings that either support or reject the inclusion of adding humans, hand-drawn drawings and visual prosody in multimedia learning. The fourth chapter introduces the research question and the related hypotheses. The following chapter, chapter five, presents the methods used to answer the research question. Here the comparative study is outlined by providing details regarding the survey participants; the infographic utilised, the procedure followed, and the survey results. In addition, chapter five highlights a statistical analysis based on the data obtained from the survey results. The findings showcased in chapter five are then discussed in chapter six. Chapter six lays out the interpretation of the study's findings, considers its limitations and implications, and suggests recommendations for future research. As customary, the concluding chapter summarises the study's outcomes.

2. Background

In this chapter, the motivation and the origin of the research question are outlined. Since Nigel Holmes' approach to designing infographics is at the centre of this study, this chapter thoroughly describes his viewpoint by providing an overview of his nine criteria. Holmes's approach is then contextualised and compared to the minimalistic approach of Edward Tufte. In addition, Tufte's methods, including graphical excellence, data-to-ink ratio and chartjunk, are briefly described in reference to the discourse between these two professionals. In conclusion, this chapter highlights how the research objective originated from this discourse.

2.1 Holmes: Joyful infographics

Nigel Holmes is an illustrator and graphic designer that has worked with well-known media houses such as the British Broadcasting Corporation and Time magazine.[22] In *"Joyful Infographics: A friendly, human approach to Data",* Nigel Homes extensively outlines his approach to creating infographics. *Joyful,* he defines as *"happily revealing the meaning",* as he advocates for allowing his audience the pleasure of understanding the data.[23] Infographics he defines loosely as information that is presented graphically; *"Infographics have a visual component—sometimes it's a pictorial presentation of the subject, sometimes abstract bars and lines".*[24] Holmes's approach can be summarised as creating infographics beyond just informing the reader. He includes elements of entertainment as the reader learns.

According to Holmes, there are nine ways to make your graphics joyful. The first criterion is to *know your audience*. Knowing your audience, he describes it as being aware of the demographic using or viewing the infographic.[25] Holmes argues that every group, including specialists, can benefit from a friendly graphic; however, it is essential not to talk down and over-simplify the data.[26] The second criterion is the use of *visual prosody* to make joyful infographics. Visual prosody, he describes as adding enjoyable or humorous imagery to the data.[27] The third criterion is using

[22] Holmes, *Joyful Infographics*, pp. 237.
[23] Holmes, *Joyful Infographics*, pp. 16.
[24] Ibid.
[25] Holmes, *Joyful Infographics*, pp. 46.
[26] Ibid.
[27] Holmes, *Joyful Infographics*, pp. 48.

context, comparisons and connections in infographics to encourage readers to compare the new information to their prior knowledge.[28] Holmes emphasises this by using the example of large sums. Large sums, he argues, are more fathomable when shown in relation to popular objects' sizes or lengths.[29] The fourth criterion is including *metaphors* in infographics. Metaphors, Holmes argues, can give insight into the information. They can communicate data with an eye-opening effect.[30] The following criterion is *clarity*. According to Holmes, instead of using graphics to simplify the information, the designer should use them to clarify the information. The goal should not be to remove the data but rather to present the required information in a digestible way to the reader.[31] *Editing* is the sixth criterion Holmes elaborates on. Holmes believes the user should not be expected to interact with every data on the topic to come to their conclusions.[32] When editing, data that are not relevant to the narrative of the infographic should be removed. *Labelling* is the seventh criterion that Holmes elaborates on. Holmes advocates for readable labels placed directly onto the image, not below or above.[33] The inclusion of *drawings* is the eighth criterion. Hand-drawn drawings, especially with perspective, can depict how the human eyes perceive objects. For this reason, Holmes emphasises that a traditional portrayal of objects can support readers in understanding the visual structure of the presented graphic.[34] The final and ninth criterion is including *humans* in infographics. Holmes states, "*a person of any kind, in a chart, gives the reader something to identify with.*"[35] He further argues that including humans increases the reader's empathy with the data, and this empathy may influence how the reader makes decisions about the represented data.[36]

The above-described criteria provide insights into what Holmes is arguing for under his brand of joyful infographics. In this paper, three of his nine criteria are implemented and used as variables in a comparative study. Narrowing down the criteria was beneficial to control variables and allow traceability of results. Also, testing every criterion would require extensive research measures that were not

[28] Holmes, *Joyful Infographics*, pp. 50.
[29] Holmes, *Joyful Infographics*, pp. 53.
[30] Holmes, *Joyful Infographics*, pp. 62.
[31] Holmes, *Joyful Infographics*, pp. 72.
[32] Holmes, *Joyful Infographics*, pp. 76.
[33] Holmes, *Joyful Infographics*, pp. 77.
[34] Holmes, *Joyful Infographics*, pp. 84.
[35] Holmes, *Joyful Infographics*, pp. 97.
[36] Ibid.

possible in this case. Meanwhile, three variables can still be insightful when comprehending how promising the human-friendly approach is regarding learning outcomes and reader engagement.

2.2 Tufte vs Holmes

Researchers and information designers have addressed the popular discourse between Edward Tufte and Nigel Holmes.[37,38] The different approaches that these two professionals represent have been perceived to be oppositional in nature.[39] Below, Holmes' approach is contextualised and contrasted with Tufte's.

To fully understand the context around Holmes' *friendly, human approach to data*, it is necessary to dive into Tufte's theoretical substance on minimalistic infographics. Edward Tufte is a statistician and Professor Emeritus of Political Science, Statistics and Computer Science.[40] He is well-known for his work in the field of Information Design, with notable publications such as *Envisioning Information* and *The Visual Display of Quantitative Information*.[41,42] One of his known concepts is *graphical excellence,* whereby he lays out fixed principles regarding the graphical presentation of information. Some of these principles include clarity, precision and efficiency, but Tufte also emphasises maximising the use of space and ink when showing data by stating, *"Graphical excellence is that which gives the viewer the greatest number of ideas in the shortest time with the least ink in the smallest space."*[43] With this, Tufte advocates for a minimalistic design approach whereby the information is shown in the least amount of space, with most of the ink in a graph used only for data ink. Data ink he defines as the ink used to show the data only, and a graphic should aim to have a 1.0 data-ink ratio.[44] The data-ink ratio can be calculated by dividing the data-ink by the total ink used to print the graphic.[45] In that sense, Tufte is strictly against using decorative measures when creating information, as it leads to an unbalanced data-

[37] Murray, *Infographic*, pp. 20.
[38] Cairo, Alberto. *The functional art: An introduction to information graphics and visualisation*. New Riders, 2013, pp. 62.
[39] Cairo, *Functional Art*, pp. 61.
[40] Edward R. Tufte Resume, edwardtufte.com, https://www.edwardtufte.com/files/ETresume.pdf Accessed 5 July 2023.
[41] Tufte, Edward R. *Envisioning Information*. Graphics Press, 1990.
[42] Tufte, Edward R. *The visual display of quantitative information*. Graphics Press, 2001.
[43] Tufte, *Visual display*, pp. 51.
[44] Tufte, *Visual display*, pp. 31.
[45] Ibid.

to-ink ratio. He uses the term *chartjunk* to describe information graphics that incorporate decorative measures and adds that these decorations are unnecessary as they do not provide new information to the viewer.[46] Tufte boldly states that the graphical work from media publications (from which Holmes originates) is under the sole direction of artistic expertise without including substantive and statistical skill sets.[47] According to him, these graphics show false information, use simple designs and miss out on crucial information from the data.[48] Finally, Tufte believes that this emphasis on an artistic approach underestimates and undervalues the audience. He states, "*Consumers of graphics are often more intelligent about the information at hand than those who fabricate the data decoration".* [49]

In his attempt to depict to his reader what he meant by chartjunk, Tufte used one of Holmes' graphs published in Time Magazine.[50,51] In this particular graph, Holmes illustrated a lady and used her legs to show the rising prices of diamonds.[52] Although Holmes is an information designer, his background differs entirely from Tufte's. Holmes' origin as a trained illustrator and designer can be observed across much of his work. Having worked for several media houses, most of his audiences have been the general public. Compared to Tufte's field of work, which has mainly been in academia. Alberto Cairo has described the dispute between Holmes and Tufte as the conflict between the engineers and designers. He describes it as such *"There has always been a fundamental clash in information graphics and visualisation between those who favour a rational, scientific approach to the profession emphasising functionality, and those who consider themselves "artists", placing emphasis on emotion and graphics."*[53] Those who favour this more scientific and rational approach come from technical backgrounds, whilst those who are graduates of design or journalism favour the emotional and decorative approach.

Over the years, there has been research that has tested Tufte's data-to-ink ratio and has proven it to be rather a subjective or preference matter and not necessarily

[46] Tufte, *Visual display*, pp. 107.
[47] Tufte, *Visual display*, pp. 87.
[48] Ibid
[49] Tufte, *Envisioning information*, pp. 34.
[50] Ibid.
[51] Cairo, *Functional Art*, pp. 63.
[52] Ibid.
[53] Cairo, *Functional Art*, pp. 61.

scientifically founded.[54],[55] Although Tufte stems from academia, his minimalistic approach to information visualisation does not automatically have legitimacy over other approaches. It is only by testing different approaches that it becomes possible to differentiate which approaches benefit which situations and which groups. This thesis attempts to merge two worlds by testing Holmes' emotional approach among a highly-educated audience. Can such an audience benefit from this approach, or should this approach remain restricted to the field of journalism? Does this approach allow for more engagement across a demographic of highly educated people, or does it instead engage less? These questions lie at the centre of this research. Testing different approaches across different groups can support the process of finding or eliminating specific strategies in the pursuit of creating informative and engaging infographics.

54 Bateman, Scott et al. "Useful Junk? The effects of visual embellishment on comprehension and memorability of charts." *Proceedings of the 28th International Conference on Human Factors in Computing Systems*, pp. 2573-2582, pp. 2573.

55 Inbar, Ohad et al. "Minimalism in information visualization: Attitudes towards maximizing the data-ink ratio." *Proceedings of the 14th European Conference on Cognitive Ergonomics*, 2007, pp. 1-4, pp.4

3. Theoretical Framework

In this chapter, multiple theories behind multimedia learning are examined, and the empirical context of the thesis is presented. First, the term infographic is defined with an emphasis on highlighting its role as a multimedia learning tool. This is then proceeded by describing multimedia learning from the perspective of Richard Mayer's *Cognitive Theory of Multimedia Learning*. With the research question in mind, theories for and against the inclusion of humans, drawings and visual prosody in multimedia learning, especially for highly-educated individuals, are presented. Theories supporting the inclusion are extensions of the *Cognitive Theory of Multimedia Learning,* which include Moreno's *Cognitive-Affective Theory of Learning with Media* and Plass & Kaplan's *Integrated Cognitive-Affective Model of Learning with Multimedia*. Alongside multimedia-related theories, recent studies on emotional design that showed promising results are also presented. On the other hand, theoretical explanations that promote the exclusion of emotion-arousing features are also discussed. These include the seductive detail effect and the expertise reversal effect.

3.1 Infographics

Infographics have been defined and described in multiple ways. These multiple definitions are a result of the multi-disciplinary nature of infographics.[56] The functionalist-idealist approach sees the infographic primarily as a scientific methodology.[57] This can be seen in the works of statisticians or mathematicians, who aim to explore data and find meaning behind it.[58,59] The pragmatist-realist discourse understands infographics as technology but in the form of visual journalism and hopes to inform.[60] Other approaches, such as the expressionist aesthete, emphasise more on the aesthetic presentation of an infographic.[61] Beyond the various interpretation across disciplines, there are other factors that complicate the generation of a universal definition for the term infographic. While some argue that

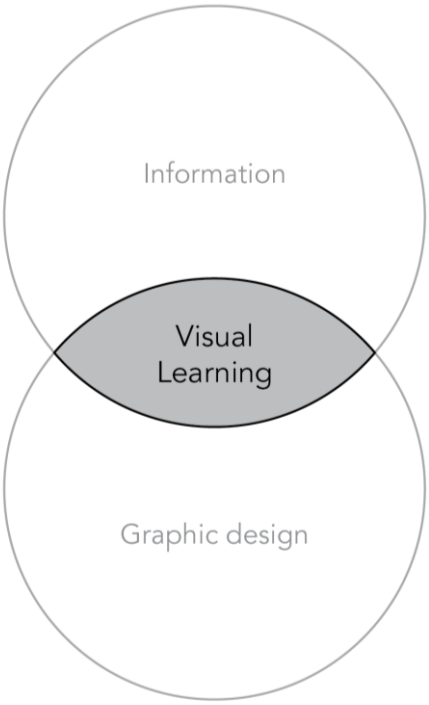
[56] Murray, Infographic, pp. 20.
[57] Ibid.
[58] Ibid.
[59] Cairo, Functional Art, pp. 62.
[60] Murray, Infographic, pp. 21.
[61] Murray, Infographic, pp. 22.

infographics should be able to convey complete stories,[62] others broaden the criteria and reject the idea of a threshold at which an item becomes an infographic. Lankow et al., for example, interpret infographics in a broader sense by including any item that provides information in imagery.[63] They include anything from road signs to complex visual analyses.[64] Alternative approaches, such as that of Cairo's, distinguish between visualisation and infographic. To him, infographic exists on a continuum together with the term visualisation. Cairo sees infographics as direct information presentations, whereas visualisations have explorative qualities.[65] But, he also admits that both incorporate a certain degree of presentation and explorative features.[66]

Across all the definitions and disciplines, the consensus is that infographics are to inhabit information and display such in graphical form as is already implied in its full-name *information graphics*.[67,68] The definition that allows for a middle ground while simultaneously fitting the context of this particular study is the perception of infographics "*as a multi-section visual display designed to communicate information using a combination of images and supporting text*".[69] In that sense, infographics here are also seen as inhabiting content that is built upon a foundation of research.[70] By using graphic design principles, the information is then transformed into visual form (see Figure 1). Furthermore, in alignment with the study of multimedia learning, infographics here are seen as a medium that promotes learning so that complex information is easily digestible. [71]

[62] Krum, Randy. *Cool Infographics: Effective Communication with Data Visualization and Design*. Wiley, 2013, pp.8.
[63] Lankow, Jason et al. *Infographics: The power of visual storytelling.* John Wiley & Sons, 2012, pp. 20
[64] Ibid.
[65] Cairo, *Functional Art*, pp. xvi.
[66] Ibid.
[67] Murray, *Infographic,* pp. 13.
[68] Holmes, *Joyful Infographics*, pp. 16.
[69] Christiansen, Jen. *Building science graphics: An illustrated guide to communicating science through diagrams and visualisation*. CRC Press, 2023, pp. 15.
[70] Christiansen, *Building science graphics*, pp. 16.
[71] Smiciklas, Mark. *The power of infographics: Using pictures to communicate and connect with your audiences*. Pearson Education, 2012, pp. 4.

Figure 1: Anatomy of an infographic by Smiciklas (2013)

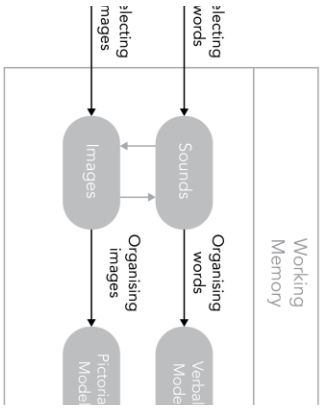


3.2 Multimedia Learning and the Cognitive Theory of Multimedia Learning.

Richard Mayer's *Cognitive Theory of Multimedia Learning* (CTML) provides a solid theoretical foundation when observing infographics as visual displays of information with the aim of informing readers. At its core, multimedia learning refers to learning from pictures and words.[72] The idea behind the theory is that learners are able to learn better when a piece of information is presented in both words and pictures and not only in words.[73] Learning, in this instance, is considered meaningful when the learner can both retain and transfer the information provided.[74] Retention here means remembering and then having the *ability to reproduce and recognise presented material*.[75] On the other hand, transfer refers to understanding the material and having the *ability to use presented material in novel situations*. [76]

[72] Mayer, *Multimedia learning*, pp. 20.
[73] Ibid.
[74] Ibid.
[75] Mayer, *Multimedia learning*, pp. 35.
[76] Ibid.

Figure 2: The CTML by Mayer (2021)



As can be observed in the figure, the CTML makes three major assumptions. First, it assumes that the human information processing system has two main channels; one for processing visual/pictorial information and the other processes auditory/verbal information.[77] This dual-channel system allows information shown to the eyes, e.g. animations or static images, to be processed by the visual/pictorial channel. The auditory/verbal channel processes information presented to the ears, e.g. narration or music.[78] The second assumption made by the CTML is that the amount of information processed by the channels at a given time is limited.[79] Meaning that the learner can only hold a limited number of images in the visual channel of the working memory at one time. The same is applicable to the auditory channel, as only a few sounds can pass through the channel at a time. The third assumption is that cognitive processing is an active process carried out by the learner themselves as they construct a coherent mental representation of the presented material.[80] Mayer claims that this cognitive process involves first the selection of relevant information, then the organising of this information into a coherent knowledge structure, and finally, integrating the information with prior knowledge.[81] As portrayed in Figure 2, the selecting, organising and integrating process occurs in a linear manner and within the structures of three different memory stores. The memory store that is first activated during the cognitive process is the sensory memory. The sensory memory picks up images and sounds in the visual and auditory sensory memory, respectively, for a brief period. These new stimuli are then consciously held and organised in working memory. The working memory then has the ability to convert and construct

[77] Mayer, *Multimedia learning*, pp. 51.
[78] Mayer, *Multimedia learning*, pp. 52.
[79] Mayer, *Multimedia learning*, pp. 53.
[80] Mayer, *Multimedia learning*, pp. 56.
[81] Ibid.

new representation modes for the incoming new information by converting either sound to images or vice versa.[82] While working memory is limited in its capacity to hold information, long-term memory holds a vast amount of knowledge.[83] Long-term memory assists with the integration part of the cognitive process, whereby it provides working memory with the prior knowledge that is then integrated with the new knowledge.[84]

When it comes to measuring the success or failure of learning outcomes, the CTLM employs an analogy of three cognitive processes to explain potential learning outcomes. The analogy derives from Sweller's *Cognitive Load Theory*, which emphasises the capabilities and limitations of human cognition.[85] Based on these capabilities and limitations, the three cognitive processes include extraneous processing, essential processing and generative processing.[86] Extraneous processing refers to a cognitive process that does not permit learning due to poor design.[87] As a result, the learner performs poorly on retention and transfer tests. In the case of essential processing, the learner is able to select and construct a verbal or pictorial representation of the information as it is presented; however, the information is not necessarily integrated into prior knowledge structures.[88] The learner then performs well in retention tests but poorly in transfer tests. Mayer argues that the most meaningful learning experience is when generative processing occurs.[89] Here the learner is able to make sense of the presented material initiated by the learner's motivation to learn. With generative processing, the learner can reorganise the new knowledge and integrate it with prior knowledge.[90] Hence, the learner may perform well in both retention and transfer tests. Mayer argues that generative processing may be achieved by promoting an engaging learning environment.[91] Therefore, on the basis of this analogy, it can be argued that an engaging infographic would motivate the reader to undergo a generative cognitive process that would permit a good performance in retention and transfer tests. In this paper, the concept of the three cognitive processes is applied, and retention and transfer tests are used to

[82] Mayer, *Multimedia learning*, pp. 58.
[83] Ibid.
[84] Ibid.
[85] Mayer, *Multimedia learning*, pp. 67.
[86] Ibid.
[87] Ibid.
[88] Mayer, *Multimedia learning*, pp. 68.
[89] Mayer, *Multimedia learning*, pp. 69.
[90] Ibid.
[91] Ibid.

measure learner performance and engagement. Generative processing is considered an indication of the best learning outcome due to optimal design principles. On the other hand, essential processing and extraneous processing are the less favourable outcomes due to suboptimal design principles.

The original theoretical assumption of the CLTM has not included motivational factors such as affect, beliefs and social presence.[92] Based on emerging results on the effects of emotional design in multimedia learning, Mayer argues that it is necessary to consider new principles that go beyond the learner's cognitive capacity.[93] He argues that the learner's affective state should be taken into consideration as well. Mayer considers emotional design to be a promising research direction that will provide a better understanding of how and when emotion-arousing features are best used to promote learning.[94] The upcoming section explores various theories that either support or oppose the utilisation of emotional-arousing features. Arguments for adding human drawings and visual prosody are mostly rooted in the expansion of Mayer CTLM and research results indicating positive impacts of emotional design. In contra, arguments against the inclusion of these features align with Sweller's Cognitive Load theory, which provides the theoretical base for the seductive detail effect and the expertise reversal effect.

3.3 Arguments for adding humans, visual prosody and drawings

3.3.1 Cognitive-Affective Theory of Learning with Media, CATLM

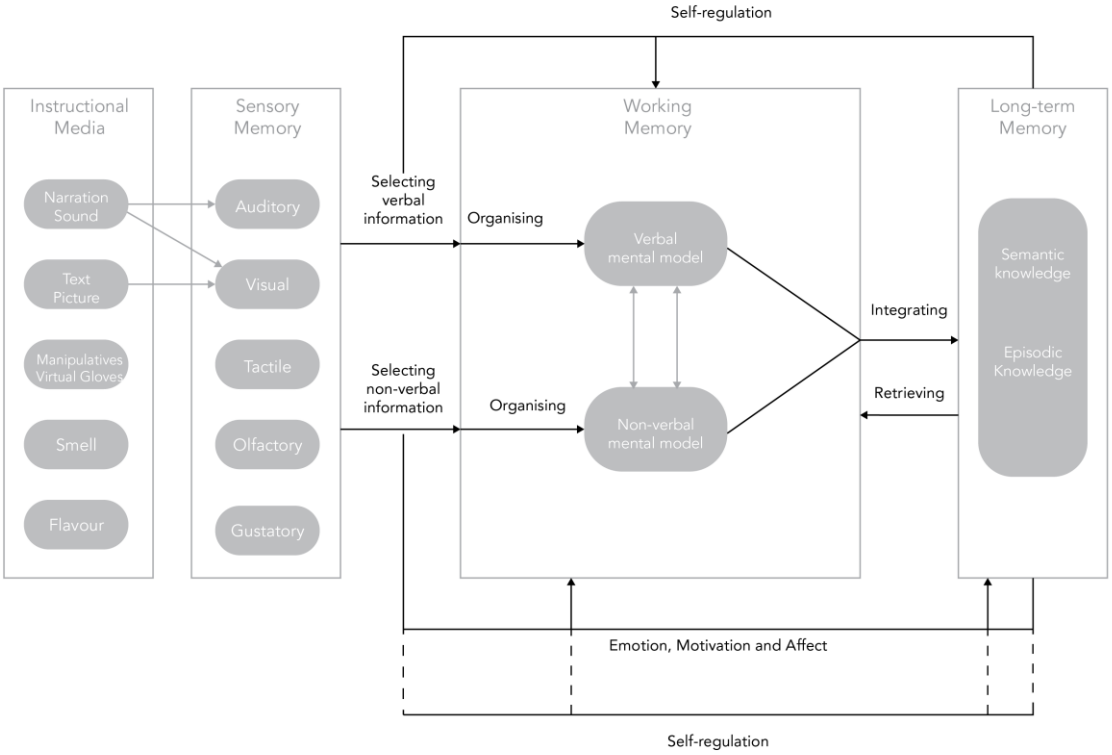
The *Cognitive-Affective Theory of Learning with Media* (CATLM), coined by Moreno, builds upon the cognitive theory of multimedia learning.[95] While the CTLM focuses on cognitive capacity as the main factor for learning processes, CATLM integrates additional metacognitive factors in the facilitation of learning.[96] CATLM emphasises that besides the limited capacity of the working memory, learning is also influenced by the interaction between the learner's prior knowledge, abilities, beliefs and motivation.[97] The cognitive capacity a learner possesses is seen as one important factor they bring to a learning task, but it is not the only determining factor for

[92] Mayer, *Multimedia learning*, pp. 74.
[93] Ibid.
[94] Ibid.
[95] Moreno, Cognitive Load Theory: More Food for Thought, pp. 137.
[96] Ibid.
[97] Ibid.

meaningful learning. Metacognitive factors are seen to be influential over a learner's cognitive capacity as they can actually determine how much resources, e.g. cognitive capacity, the learner invests in the learning task.[98] At its core, the CALTM provides the learner with more agency and acknowledges that learners carry with them certain conditions that affect their learning process. By considering metacognitive factors, there can be a better understanding of if and how emotional imagery can motivate and emotionally impact learners and, therefore, their capacity for learning. The ideal outcome is that emotion-arousal imagery and words affect the learners in a manner that encourages them to invest more effort in learning.

[98] Moreno, Cognitive Load Theory: More Food for Thought, pp. 138.

Figure 3: CATLM BY Moreno (2006)



3.3.2 Emotional Design and Integrated Cognitive-Affective Model of Learning with Multimedia

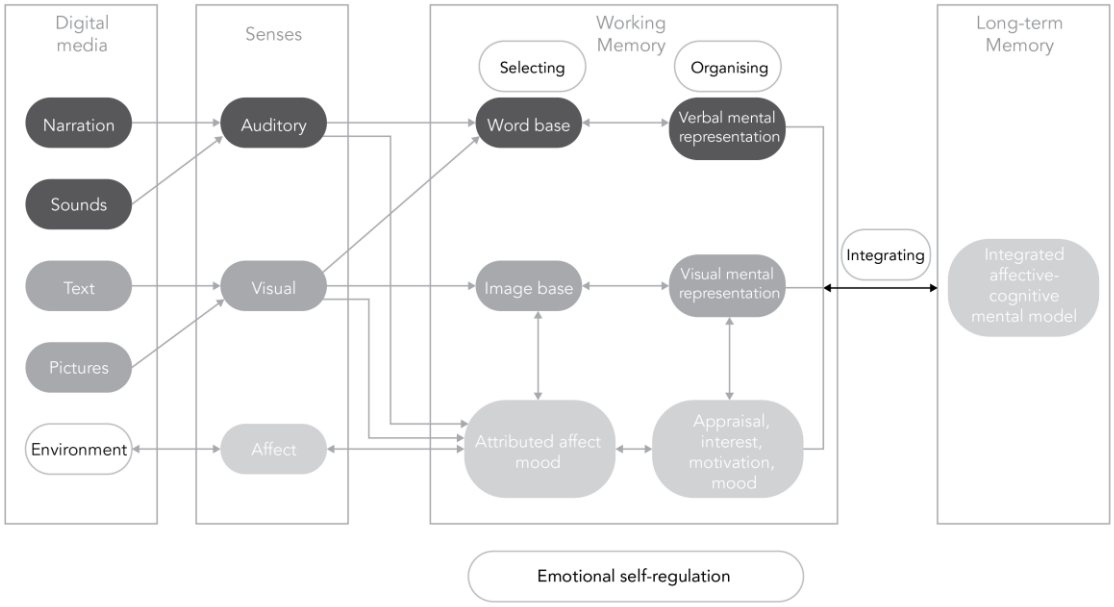
Emotional design is defined as the *use of a range of design features with the goal of impacting learners' emotions to enhance learning*.[99] The inclusion of emotional features in learning material has been grounded on multiple theories and research findings. Among them are the results brought forth by scholars studying emotion research and affective neuroscience, who have been able to show that emotions are formative in basic cognitive mechanisms, such as memory, attention, and perception.[100] Upon this finding, a paradigm shift in educational technology and learning sciences allowed a greater recognition of emotions in cognitive processes.[101] Furthermore, learners are being perceived more as *complete beings motivated to action by a complex system of emotions, drives, needs and environmental conditioning*.[102]

[99] Plass & Kaplan, Emotional Design in Digital Media for Learning, pp.138.
[100] Plass & Kaplan, Emotional Design in Digital Media for Learning, pp.135.
[101] Ibid.
[102] Picard, Rosalind W. & Jonathan Klein. "Computers that recognise and respond to user emotion: theoretical and practical implications." *Interacting with Computer*, vol 14, 2002, pp. 141-169, pp.142.

Izard belongs to the scholars that made the connection between emotion, cognition and motivation through his concept of emotion schemas. He defines emotion schema *as emotion-cognition interactions/structures that generate feeling-thought experiences and behavioural tendencies*.[103] Which acknowledges that emotions are capable of motivating cognition and behaviour by having *"special and powerful effects on self-regulation and on perception, thought, and action."*[104] In the context of multimedia learning, Plass & Kaplan uses Izard's emotion schema to argue that the multimedia environment can cause affective responses among learners as they perceive auditory or visual information.[105] This response in a learner is what they refer to as the *core affect*. This core affect impacts how and what information the learner selects, organises and integrates into their working memory.[106] As this theory is built upon the CTLM and the CALTM, Plass & Kaplan refer to the theory as *the Integrated cognitive-affective model of learning with multimedia* (ICALM).[107] The difference between the CALTM and the ICALM, is that the ICALM sees the core affect as an inseparable part of the cognitive process and not just as a condition. As illustrated in Figure 4, affect is integral to the learning process.

[103] Izard, Emotion Theory and Research pp. 3.
[104] Izard, Emotion Theory and Research pp. 9.
[105] Plass & Kaplan, Emotional Design in Digital Media for Learning, pp. 150.
[106] Ibid.
[107] Ibid.

Figure 4: ICALM by Plass & Kaplan (2016)



When it comes to the research findings related to emotion-cognitive experiences, positive emotions have been shown to be supportive of information processing, communication, creative problem-solving, decision-making and a higher level of cognitive activities.[108] In multimedia learning, design elements related to emotional design, including warm colours, positive imagery and anthropomorphism, have also shown promising results when it comes to their ability to induce positive emotions, motivate and enhance learning.[109,110] Furthermore, a meta-analysis of 33 independent samples identified that pleasant colours and anthropomorphic features are generally useful design principles when aiming to improve learning and intrinsic motivation.[111] In addition, Wong confirmed again through a meta-analysis of more recent experiments that emotional design elicited positive emotions and, as a result, enhanced retention, comprehension and transfer performances.[112]

Some emotional design features are more researched than others. The effects of using visual prosody/humour and hand-drawn drawings in multimedia learning are

[108] Norman, *Emotional design*, pp. 19.
[109] Park, Babette et al. "Emotional Design and Positive Emotions in Multimedia Learning: An Eyetracking Study on the Use of Anthropomorphisms." *Computers & Education*, vol. 86, Elsevier BV, Aug. 2015, pp. 30–42, doi:10.1016/j.compedu.2015.02.016. pp.30.
[110] Plass, Jan et al. Emotional design in multimedia learning: Effects of shape and color on affect and learning. *Learning and Instruction*. 29, 2014, pp. 128–140. 10.1016/j.learninstruc.2013.02.006. pp. 128.
[111] Brom, How Effective Is Emotional Design, pp. 100.
[112] Wong, Meta-Analysis of Emotional Designs, pp. 357.

features that require further examination. Among the few existing research on humour is a study conducted by Dorambari whereby he observed that humour had no significant benefits to the cognitive process, but it was also not harmful either.[113] Then again, in the case of asynchronous online learning, Erdoğdu and Çakıroğlu were able to observe a positive influence on cognitive engagement when humour was applied.[114] In addition, Vance's study on the use of humour in instructional design could also confirm a positive effect on retention.[115] However, the limited and multi-directional results on the topic suggest that further research is required on the matter. When it comes to drawing style, research has shown that the style of a diagram does matter when it comes to learning. For example, this was analysed when testing diagram fidelity, whereby increasing visual fidelity along with lesson progression was observed to be beneficial to learning outcomes.[116] In a related area of research, Butcher identified that simple illustrations encouraged better learning outcomes than detailed illustrations.[117] These studies indicate that drawing style does have an effect on learning. Research, however, studying the effect of a more emotional style of drawing through the use of hand-drawn drawings compared to computerised drawings in visual representation still remains underrepresented. Further testing is necessary to observe large-scale tendencies when implementing specific emotional design features such as visual prosody/ humour or hand-drawn illustrations. In comparison, the use of adding human features to non-human objects referred to as anthropomorphism, has been researched more frequently and shown to be effective in improving learning outcomes.[118,119] In this paper, using human figures is seen as relatively similar to using anthropomorphism in multimedia learning. In general, the study not only expands on previous research on emotional

[113] Dorambari, Dodien. Investigating the Effects of Instructional Humor in Multimedia Learning when Humor Pre-Disposition, Prior-Knowledge, and Working Memory are Controlled, *International Journal of Education and Practice*, Conscientia Beam, vol. 10(2), 2022 pp. 182-203, pp. 182.
[114] Erdogdu, Ferruh, and Ünal Çakıroğlu. "The Educational Power of Humor on Student Engagement in Online Learning Environments." *Research and Practice in Technology Enhanced Learning,* vol. 16, no. 1, Springer Nature, Apr. 2021, pp. 1-25, doi:10.1186/s41039-021-00158-8, pp. 1.
[115] Vance, Charles M. "A Comparative Study on the Use of Humor in the Design of Instruction." *Instructional Science*, vol. 16, no. 1, Springer Science+Business Media, Jan. 1987, pp. 79–100, doi:10.1007/bf00120007. pp.79.
[116] Joo, Hyun, et al. "Visual Representation Fidelity and Self-explanation Prompts in Multi-representational Adaptive Learning." *Journal of Computer Assisted Learning*, vol. 37, no. 4, Wiley-Blackwell, Apr. 2021, pp. 1091–106, doi:10.1111/jcal.12548. pp. 1091.
[117] Butcher, K. R. (2006). Learning from text with diagrams: Promoting mental model development and inference generation. *Journal of Educational Psychology*, 98(1), 182–197. https://doi.org/10.1037/0022-0663.98.1.182, pp. 182.
[118] Mayer & Estrella, Benefits of Emotional Design, pp. 12.
[119] Brom, How Effective Is Emotional Design, pp. 100.

design by incorporating more novice features but also adds value by examining their implementation in a particular combination.

3.4 Arguments against adding humans, visual prosody and drawings

3.4.1 Seductive Detail

Seductive details are exciting elements added to the learning material without providing any relevant information.[120][121] The research on the impact of seductive details on learning has been contradictory.[122],[123] Some experiments have shown the negative impacts of seductive details on learning, whilst others have identified the opposite. Two meta-analyses examining numerous experiments have revealed that seductive details tend to impact the learning process negatively.[124,125] The results indicated that when considering all modes of seductive detail (i.e. audio, text-based or imagery-based) in several learning contexts, generally, seductive detail does hinder learning.[126,127] This negative impact has been backed by the Cognitive load theory, whereby the seductive details are seen as extraneous material that overloads the working memory.[128] Although seductive details tend to be negatively impactful, research has also shown that their impact is more nuanced and highly situational.[129] Park et al. were able to show that seductive details have the potential to foster learning in low-load conditions, such as in the case of accompanied verbal explanations.[130] Then again, the results showed that seductive details are not beneficial to learning in high-load conditions when on-screen text alongside seductive details is presented to learners.[131] In the case of emotion-arousing seductive details, Schneider et al. discovered that positively-valenced decorative

[120] Mayer, Richard E. "Taking a New Look at Seductive Details." *Applied Cognitive Psychology*, vol. 33, no. 1, Wiley-Blackwell, Jan. 2019, pp. 139–41, doi:10.1002/acp.3503. pp. 139.
[121] Harp, Shannon F. & Mayer, Richard E.. "How Seductive Details Do Their Damage: A Theory of Cognitive Interest in Science Learning." *Journal of Educational Psychology*, vol. 90, no. 3, American Psychological Association, Sept. 1998, pp. 414–34, doi:10.1037/0022-0663.90.3.414. pp.414
[122] Mayer, Taking a New Look at Seductive Details, pp. 139.
[123] Park, Babette & et al. "Does Cognitive Load Moderate the Seductive Details Effect? A Multimedia Study." *Computers in Human Behavior*, vol. 27, no. 1, Elsevier BV, Jan. 2011, pp. 5–10, doi:10.1016/j.chb.2010.05.006, pp. 5.
[124] Sundararajan, Keep It Coherent, pp. 707.
[125] Rey, Günter Daniel. "A Review of Research and a Meta-analysis of the Seductive Detail Effect." *Educational Research Review*, vol. 7, no. 3, Elsevier BV, Dec. 2012, pp. 216–37, doi:10.1016/j.edurev.2012.05.003. pp. 216.
[126] Sundararajan, Keep It Coherent, pp. 707.
[127] Rey, A Review of Research and a Meta-analysis of the Seductive Detail Effect, pp. 216.
[128] Rey, A Review of Research and a Meta-analysis of the Seductive Detail Effect, pp. 217.
[129] Mayer, Taking a New Look at Seductive Details, pp. 139.
[130] Park, Does Cognitive Load Moderate the Seductive Details Effect, pp. 5.
[131] Ibid.

pictures that were without relevant information fostered learning among university students.[132] In other instances, Kuhl found no significant impact on learning from emotion-arousing, text-based seductive details.[133] The variance in the experiments studying the impact of seductive details suggests that their effect on learning may be highly situational. Based on this actuality, testing the effect of different forms of seductive details across various media formats remains essential. In essence, the inclusion of humans, drawings, and visual prosody can be deemed seductive details since they do not offer meaningful information to the learner. In the eventuality of a negative impact, the *cognitive load theory* could provide a possible explanation for this outcome.

3.4.2 Expertise Reversal Effect

Research within the theoretical framework of the *cognitive load theory* context has shown that design techniques that are effective among low-knowledge learners can be less effective or even disadvantageous to high-knowledge learners.[134] This phenomenon is referred to as the *expertise reversal effect*.[135] Klayuga defines it as such; "*the reversal in the relative effectiveness of instructional methods as levels of learner knowledge in a domain change"*[136] Kalyuga borrows the term *cognitive architecture* from the cognitive load theory, as he provides a theoretical explanation for this effect.[137] Cognitive architecture, he describes as the *general cognitive system that underlies human performance and learning*.[138] There are three main takeaways from this concept. The first is that cognitive architecture is founded upon knowledge structures in the long-term memory, which has unlimited capacity.[139] This is not the case when it comes to working memory. This aligns with the second aspect, which describes how the working memory limits the scope of new information entering the knowledge base[140]. Thirdly, in the case of working memory limitations, the cognitive

[132] Schneider, Sascha. "Decorative Pictures and Emotional Design in Multimedia Learning." *Learning and Instruction*, vol. 44, Elsevier BV, Aug. 2016, pp. 65–73, doi:10.1016/j.learninstruc.2016.03.002, pp. 65.
[133] Kühl, Tim, et al. "Adding Emotionality to Seductive details-Consequences for Learning?" *Applied Cognitive Psychology*, vol. 33, no. 1, Wiley-Blackwell, Nov. 2018, pp. 48–61, doi:10.1002/acp.3477, pp. 48.
[134] Kalyuga, Slava. "Expertise Reversal Effect." Cognitive load theory, edited by John Sweller, et al., 2011, pp. 155-169, pp. 155.
[135] Kalyuga, Expertise Reversal Effect, 2011, p. 155.
[136] Kalyuga, Slava. "Expertise Reversal Effect and Its Implications for Learner-Tailored Instruction." Educational Psychology Review, vol. 19, no. 4, *Springer Science+Business Media*, Sept. 2007, pp. 509–39, doi:10.1007/s10648-007-9054-3, pp. 510.
[137] Kalyuga, Expertise Reversal Effect and Its Implications for Learner-Tailored Instruction, 2007, pp. 510.
[138] Ibid.
[139] Ibid.
[140] Ibid.

architecture is able to coordinate cognitive load reduction activities by using knowledge structures in long-term memory and treating them as knowledge in working memory.[141]

Based on the setup of the cognitive architecture, Kalyuga argues that cognition would operate best if basic lower-level mental processes were excluded so that most cognitive resources remain available for higher-level operations that are required during thinking, learning and problem-solving.[142] In addition, he argues that long-term memory has an *executive function* during cognitive activities because it governs the content and characteristics of the working memory during complex cognitive activities.[143] The execution function, he argues, can become unbalanced when surplus information intended for novice learners is given to knowledgeable learners.[144] This can cause them to have to reconcile the surplus information with their existing knowledge, which adds an additional working memory load and reduce resources available for new knowledge.[145] Hence causing the *expertise reversal effect*. As summarised by Kalyuga, there is enough empirical evidence that has shown this effect to be impactful in diverse contexts.[146]

Regarding emotional design and its impacts on learners' expertise, Chiu et al. have found that emotional design supports low-order thinking skills, such as remembering or identifying across knowledge levels.[147] However, this impact is then limited and not of significance for complex cognitive activities such as comprehension.[148] To high-knowledge learners, when it comes to comprehension, emotional design elements act as mere decorations and do not provide any benefits or drawbacks. Generally, limited research has studied the relationship between emotional design in multimedia and the expertise reversal effect.[149]

It is to be noted that the target group of this particular paper is highly educated individuals and not experts. Highly educated learners cannot be equated to Kalyuga's definition of expertise, which he describes as *the availability of a large*

[141] Ibid.
[142] Ibid.
[143] Kalyuga, Expertise Reversal Effect and Its Implications for Learner-Tailored Instruction, 2007, pp. 511.
[144] Kalyuga, Expertise Reversal Effect and Its Implications for Learner-Tailored Instruction, 2007, pp. 512.
[145] Ibid.
[146] Kalyuga, Expertise Reversal Effect and Its Implications for Learner-Tailored Instruction, 2007, pp. 516-51.
[147] Chiu, Thomas K. F., et al. "Does Learner Expertise Matter When Designing Emotional Multimedia for Learners of Primary School Mathematics?", *Educational Technology Research and Development*, vol. 68, no. 5, Springer *Science+Business Media*, Apr. 2020, pp. 2305–20, doi:10.1007/s11423-020-09775-4, pp. 2305
[148] Chiu, Does Learner Expertise Matter When Designing Emotional Multimedia, pp. 2305.
[149] Ibid.

number of domain-specific organised knowledge structures.[150] However, the expertise reversal effect remains to be considered, as it is highly probable that many survey participants have already come across the information presented in the infographic to some extent. Especially the participants who work in the sustainability field who may have a good understanding of or interest in sustainable transportation. In the case of a negative impact caused by emotional design features, the expertise effect may provide a possible explanation.

[150] Kalyuga, Expertise Reversal Effect and Its Implications for Learner-Tailored Instruction, 2007, pp. 511.

4 Research Question

The objective of this research is to investigate if the inclusion of humans, drawings and visual prosody in infographics has an effect on learning outcomes and audience engagement levels. Particularly if this effect adds educational value to infographics. The scope of this study is concentrated on an audience group with a higher educational background. In that sense, the null and alternative hypotheses are formulated in the following manner:

H0: Participants with higher education that are provided with infographics with emotional design features, including human figures, drawings, and visual prosody, achieve the same learning outcomes as those who are provided with infographics without such features.

H1: Participants with higher education that are provided with infographics with emotional design features, including human figures, drawings, and visual prosody, do not achieve the same learning outcomes as those who are provided with infographics without such features.

In the case of a significantly higher performance level by the treatment group, the features will be considered as adding educational value to infographics. This performance level is purely based on the results provided by the retention and transfer tests taken by each participant. Logically in the case of no significant difference or a significantly lesser performance by the treatment group, the claim of added educational value will be rejected.

5. Methodology

This chapter outlines the methodological approach employed to answer the research question. The approach involved a comparative study in the form of surveys. Below, the chapter provides thorough details on the participant's backgrounds and how they were recruited. Proceeding this, the infographic utilised in the survey is described on the basis of its content, macrostructure and microstructure. The two different versions of the infographic used either by the treatment or control group are then compared. Next, the survey's procedural steps are outlined. Followed by an evaluation of the data obtained from the surveys and concluding with a statistical analysis of the evaluated data.

5.1 Participants

In total, 42 participants took part in the study. To participate, individuals were required to have a university-level education, regardless of their field of study. They were also only allowed to participate if they had not previously read the infographic used in the study. The majority of participants were contacted via two mailing lists. In the email, the participants were told that the study is based on innovative science communication methods. They were to choose one of two surveys by clicking on one of the two provided links that led them to one of the two surveys. The mailing lists were that of two non-profit organisations that specialise in research projects involving climate change, nature conservation, mobility etc. The first organisation, the Institute for Climate Protection, Energy and Mobility e.V. (IKEM), is based in Berlin. The second organisation, Seychelles Islands Foundation (SIF), is located in Seychelles and works internationally with scientists from Europe as well as Seychellois scientists. The remaining participants of the study were contacted personally. These included fellow students and personal acquaintances. The assignment of the participants to the survey occurred randomly, and the participation was anonymous. Finally, 21 participants took part in the controlled study with the exclusion of Holmes' criteria, and 21 belonged to the treatment group, which included Holmes' criteria. Participants were asked to classify their knowledge of mobility and transportation. In the control group, 2 self-identified as highly knowledgeable, 15 as average and 3 as poorly knowledgeable. The remaining 1

participant did not provide an answer. In the treatment group, 3 self-identified as highly knowledgeable, 14 as average and 4 as poorly knowledgeable. It is, therefore, acceptable to argue that, in general, the level of self-perceived knowledge among participants was more or less equal across both groups.

5.2 Material

The type of infographic utilised for the survey aims to inform the reader about the specific subject matter. As defined earlier, the infographic at hand operates as *a multi-section visual display of information*. In the following section, a detailed breakdown of the content, macrostructure, and microstructure of the infographic is provided. The methods used for structuring and visualising the information are thoroughly examined. Finally, a distinction is made between the infographics used in the treatment group and the control group.

5.2.1 Infographic: Content

The infographic is based on research conducted by two research associates at IKEM. It describes the role that the Covid-19 pandemic played in the emergence of pop-up bike lanes in Friedrichshain-Kreuzberg, Berlin. Its main focus point is the description of the legal and administrative aspects that allowed the establishment of these temporary bike lanes. In addition, it makes the distinction between the administrative advantages of installing pop-up bike lanes in comparison to the instalment of permanent bike lanes. Furthermore, the infographic highlights drivers and barriers that either foster or hinder the process of installing pop-up bike lanes. Another important aspect outlined is the process of steadying pop-up bike lanes and turning them into permanent bike lanes. As a final focus point, the infographic highlights the role of pop-up bike lanes as a sustainable solution while discussing the requirements for a mobility transition. At its core, the infographic advocates pop-up bike lanes as a quick solution to creating more climate-friendly cities. The content is founded upon scientific research methods through literature analysis and interviews with experts on the subject matter.

5.2.2 Infographic: Macrostructure

When it comes to the organisation of several information pieces, the infographic uses conventional practices to provide the reader with a sense of orientation. Orientation itself is seen as a necessity, as humans require a sense of structure in the sense-making process.[151] The infographic at hand applied this concept and provided the reader with the necessary navigational tools when reading the poster. For example, as a common practice, the poster title is placed at the very top of the page, exactly where the reader would expect it to be. This facilitates the reader and provides them with a sense of order. Assuming the reader's native language reads left to right, the tendency would then be to read the text starting from the upper left and ending at the lower right of the poster. The infographic followed this convention as well, and the text is placed along that natural eye path. Orientation is also provided to the reader through the use of the gestalt principles. To ensure clear differentiation between subtitles and body text, the principle of hierarchy was applied by making titles and subtitles bold and larger in size.[152] The subtitles provide a brief overview of each paragraph's content, giving the reader an idea before diving into the full body text. Additionally, the Gestalt principle of sequence was applied by organising information in a way that requires the reader to read the information at the top prior to understanding the information at the bottom and not vice versa.[153] The Gestalt principle of proximity was also utilised by placing the text and related imagery next to each other.[154]

5.2.3 Infographic: Microstructure

Regarding the individual elements on the infographic, multiple approaches were used based on the element's role in the infographic. The first and most apparent feature to be seen on the infographic is the eye-catcher. Ballstaedt describes the eyecatcher as followed; *"Dies ist eine Bezeichnung für Reize, welche die unwillkürliche Aufmerksamkeit reflektorisch auf sich ziehen. Dabei ist meist unser biologisches Erbe im Spiel, es geht um Reize, die Sexualität, Aggression und Brutpflege betreffen."*[155] Basically,

[151] Stapelkamp, Torsten. *Informationsvisualisierung Web – Print – Signaletik Erfolgreiches Informationsdesign: Leitsysteme, Wissensvermittlungund Informationsarchitektur*. Springer Verlag, 2013, pp. 260.
[152] Lipton, Ronnie. *The Practical Guide to Information Design*. John Wiley & Sons, 2007, pp. 26.
[153] Lipton, *The practical guide*, pp. 26.
[154] Lipton, *The practical guide*, pp. 19.
[155] Ballstaedt, Stefen-Peter. Kognitive Verarbeitung von multikodaler Information, edited by M. Eibl, H. Reiterer, et al., *Knowledge Media Design*, 2nd ed., Oldenboug Wissenschaftsverlag, 2006, p115-128, pp. 118.

the eye-catcher is understood here as an attention grabber. The eye-catcher would be amongst the first places that the reader would look at.[156] In the case of the infographic, the eye-catcher is the larger graphic on the upper middle part of the poster. The image depicts the three phases of the pop-up bike lane project in Berlin. First at the far back is the pre-pop-up bike lane period showing a lack of bike infrastructure and high car traffic. Then there is the introduction of pop-up bike lanes, which is made apparent with a label and also with temporary bike infrastructures, including yellow markings and movable bollards. At the forefront of the image is the utopia. Here the pop-up bike lanes have become permanent ones, and this is communicated with a label and permanent bike infrastructures, which are white road markings, unmovable bollards and a bike road sign.

Another element high in the hierarchal structure of the poster is the introductory box. This introductory box is at the top right of the infographic, and it provides the reader with general information. It states the research question, defines and visualises pop-up bike lanes and provides basic information on the Friedrichshain-Kreuzberg district. Since readers and survey participants are of multiple academic as well as cultural backgrounds, they were not expected to know the specifics of the pop-up bike lanes and the district of Friedrichshain-Kreuzberg. The contextual information provided all readers with the specific knowledge required to engage in further reading and understanding. It makes sure that the readers are more or less well-equipped for what's to be discussed later. The pop-up bike lanes are presented in both visual and textual forms. The text and the image share a complementary relationship as both provide separate information whilst adding value to each other.[157] Although the text indicates the time and location, it falls short in describing the physical arrangement of the pop-up bike lanes. The imagery is more successful in providing information on their physicality. The graphic contrasts the pop-up bike lane with a permanent bike lane and makes a clear distinction between the two. The same approach was used to provide information on Friedrichshain-Kreuzberg. The district location in Berlin is shown in map form, and the related statistics are given in the form of complementary text. Again the relationship between text and image is one that is complementary. Detailing Friedrichshain-Kreuzberg in map form and

[156] Ballstaedt, *Kognitive Vearbeitung*, pp. 118.
[157] Alexander, Kerstin. *Kompendium der visuellen Information und Kommunikation*. Springer-Verlag, 2007, pp. 131.

adding statistics to the map was the solution to introducing the district to an international audience. By having a certain understanding of the district, the audience can also understand the scope of the research presented to them.

The entire body of the poster included 6 major text blocks, 3 expert quotes and 3 visualisations. The text blocks had roughly 200 words. Each block dealt with a specific body of information. They were organised according to a certain hierarchy, as they all had large bold subheadings, and the body text was smaller and regular. Within the body text, the major statements were highlighted in bold as a way to alert the reader to the most vital information.

The three quotes added value to the infographic by personalising the information. They represented expert opinions on the subject matter and were treated as a distinct category of information. Therefore, they were highlighted through the use of white boxes and yellow circles. They also stood out as they were written bigger than the body text.

Other distinct elements included three visualisations that were related to the information in the body text. This included a table and two flowcharts. The table makes a distinction between drivers and barriers in the process of installing pop-up bike lanes. It uses icons and texts to provide the aforementioned information. The table here is a suitable visualisation as it makes a clear distinction between the two categories within the information. The concept of the drivers and barriers is presented as opposing forces, emphasizing their distinct differences. Also, the use of icons gave the reader a break from large text blocks. The other two visualisations were flowcharts. The first flowchart shows the three steps required when converting pop-up bike lanes into permanent ones. The second flowchart emphasises the distribution of workload when installing bike lanes in the particular case when pop-up bike lanes have already been installed. Again flowcharts here were the suitable visualisation as they are conventionally used to show steps in processes.

5.2.4 Infographic: Treatment vs Control Group

Both versions of the infographic contained the same text with the exact number of words (approx. 1000 words). They also had the exact layout and structure. The only differences were the presence/absence of humans, hand-drawn/computerised diagrams and the presence/absence of visual prosody in the imagery. Allowing only a

certain degree of diversion made the two infographics comparable on the basis of Holmes' criteria, which then allows the results to be traceable to these criteria alone. Below are a series of images that showcase the differences between the infographics used. The presence or absence of humans in the infographic could be observed in several visualisations on the infographic. Figure 5 to 7 shows examples of this. In these figures, the difference between hand-drawn and computerised drawings can be observed as well. Figures 8 and 9 show where visual prosody was applied and removed in the infographic. In addition, the application of hand-drawn and computerised drawings is showcased as well.

Figure 5: Presence vs absence of humans in the eyecatcher.

Figure 6: Presence vs absence of human and hand-drawn vs computerised drawings in pop-up bike lane visualisation.

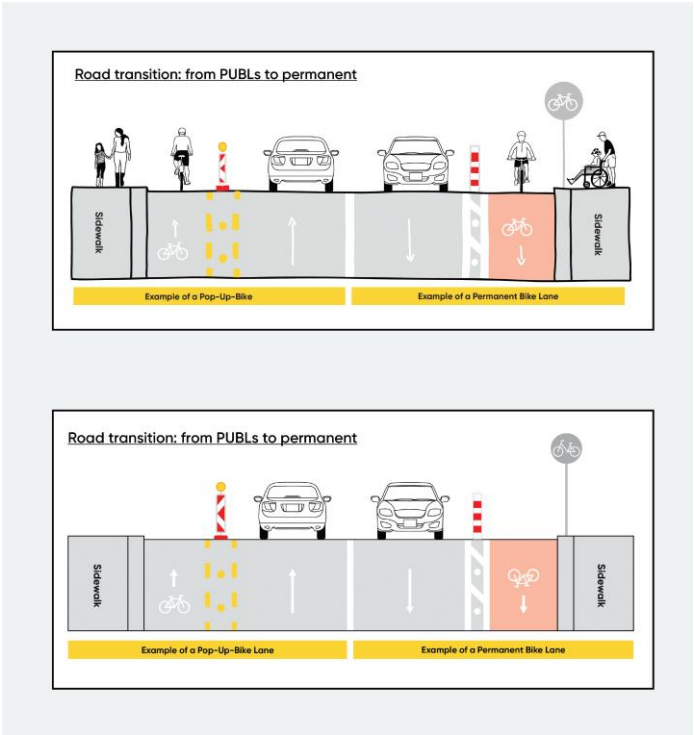


Figure 7: Presence vs absence of humans in the presentation of quotes.

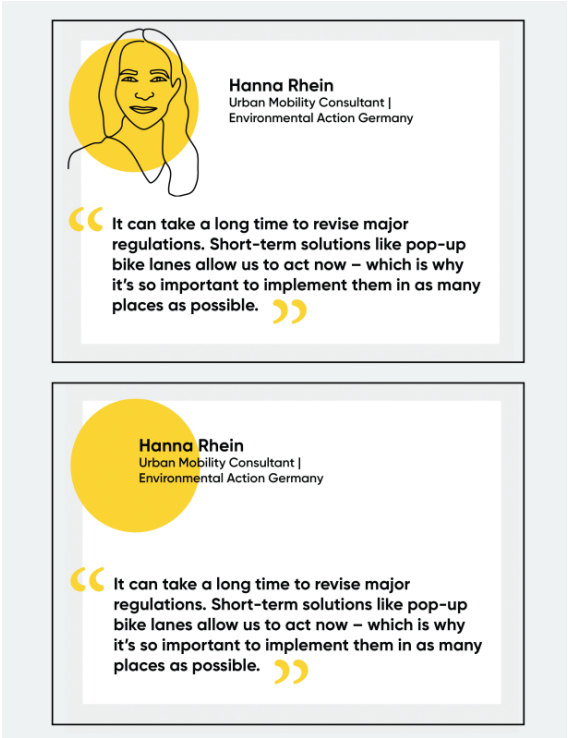


Figure 8: Visual prosody through the depiction of race to end goal. Hand-drawn vs computerised drawings can be observed in the depiction of the flowchart and the road barriers.

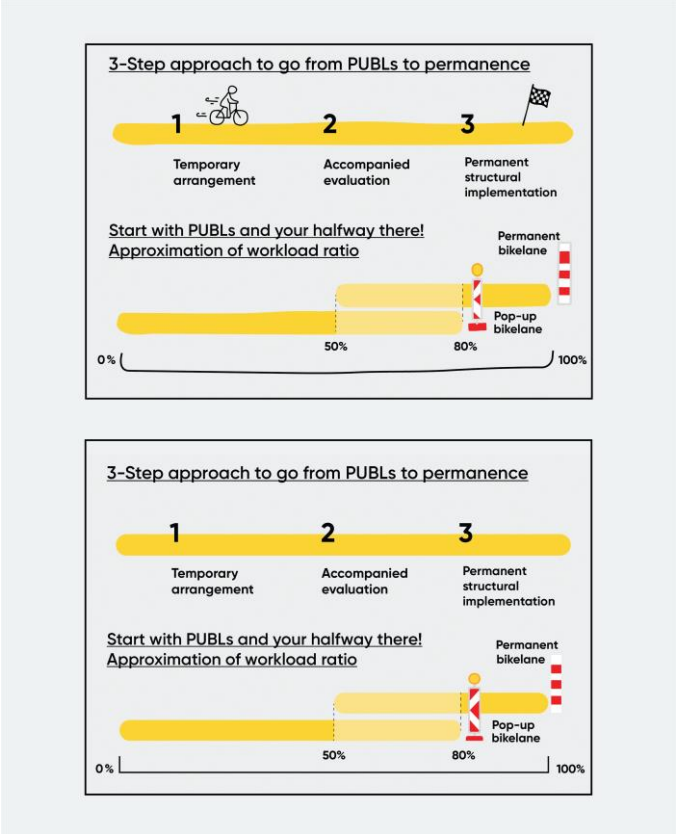


Figure 9: Visual prosody through the addition of traffic lights representing barriers and drives. Hand-drawn vs computerised drawings can be observed in the depiction of the icons and table columns and rows.

5.3 Procedure

The survey itself was conducted online and was split into two parts. The first part required the participants to read through the infographic, and during the second part, the participants answered retention and transfer questions based on the infographic. As soon as the participants clicked on the link to the survey, they were welcomed by the start page that thanked them for their participation. They were informed that the study has two parts and that they first had to download and read through an infographic for a maximum of 10 minutes.

After reading, the participants were instructed to close the infographic and answer the questions that followed. Right before answering the questions, the participants were explicitly reminded that it is essential that the infographic remains out of sight as they reply to the inquiries. The first question asked the participants to choose their level of knowledge on mobility and transportation between three available choices; highly knowledgeable, average and poorly knowledgeable. Right after making their choice, the participants were asked three retention questions and three transfer questions.

The first three retention questions were *"1.What are pop-up bike lanes? 2.In which city were they installed? 3.Name one barrier and one driver in the process of installing pop-up bike lanes."* (see Figure 10) These questions required the participant to remember specific wording from the infographic. The three transfer questions were "*4.Explain why it can be beneficial to install pop-up bike lanes before installing permanent bike lanes." "5.Can pop-up bike lanes change the entire transport system? Elaborate on your answer." "6.How can bike lanes, in general, be beneficial in urban areas?"* (see Figure 10). In order to answer these transfer questions, the participants needed to possess a more thorough comprehension of the infographic. They would need to make certain connections between the facts mentioned in the infographic and their own prior knowledge. Also, here the participants had to answer through the use of their wording as the questions called for them to explain or elaborate. If able to answer correctly, the participants were able to organise the new knowledge and integrate it in a suitable context. After replying to all questions, participants were thanked for their participation.

5.4 Results

The surveys were evaluated based on the accuracy and completeness of the answers. Taking into account both implicit and explicit information communicated by the infographic. As previously mentioned, exact wording was not expected, especially in the case of transfer questions. However, it was crucial that the responses demonstrated a good level of understanding. The first three retention questions were allocated 1 point each. With the exception of question three, since this retention question had two parts. The transfer questions were given 2 points due to their inherent complexity. In this case, 1 point was given for a partially correct answer, while a complete correct answer earned 2 points. In total, a maximum of 10 points was awarded if all questions were answered correctly. Participants were unaware of this point system and therefore replied independently.

Figure 10: Survey questions and suitable answers

Questions	Answers
1. What are pop-up bike lanes? (1pt)	Temporary bike lanes
2. In which city were they installed? (1pt)	Berlin
3. Name one barrier and one driver in the process of installing pop-up bike lanes. (2pt: 1pt each)	Drivers: Committed leader, good cooperation across administrative levels, Window of opportunity (Covid-19) Barriers: Reluctant administration, old administrative structures & ideologies, lack of resources
4. Explain why it can be beneficial to install pop-up bike lanes before installing permanent bike lanes. (2pt)	Cheaper Faster process Evaluation advantages
5. Can pop-up bike lanes change the entire transport system? Elaborate on your answer. (2pt)	No a paradigm change at federal and legislative level is required
6. How can bike lanes, in general, be beneficial in urban areas? (2pt)	Healthy and climate-mobility solution in cities

The responses provided by the participants were evaluated using the answers displayed in Table 3 as metrics. The first two questions had fixated answers. If the answers lack these specific answers, then no points were awarded. In the case of question three, the participants had several answers to choose from. If one of three possible answers in naming the drives and barriers were provided, then one point was awarded to each part of the question. The same is to be said of question four. If two of three key phrases were part of the participant's answer, then 2 points were awarded. If only one of the three key phrases was mentioned, then only one point was given. If the answers missed all three, then no points were awarded. In the case of question five, 2 points were granted if the answer included or suggested a requirement for change or shift at a higher level. If the participants answered that pop-ups might have an impact or that they can be part of the change, one point was given as this answer is in itself partly correct, but at the same, it is an incomplete answer. The sixth and final question provided participants with a chance to demonstrate their comprehension of why additional bike lanes should be installed in the first place. The two points were only given if participants gave more than one benefit or at least an answer that suggests multiple benefits in relation to climate or human health. The tables in Figures 11 and 12 showcases the number of points won by each group, and the histogram in Figure 13 shows the distribution of scores in the two groups.

Figure 11: Points awarded to the treatment group

Question	Correct answers	Wrong answers	Partially correct answers	Points awarded
1.	21	0		21
2.	20	1		20
3. (a)	17	4		17
3. (b)	15	6		15
4.	14	0	7	35
5.	9	6	6	24
6.	21	0	0	42
Total	**117**	**17**	**13**	**174/210**

Figure 12: Points awarded to the control group

Question	Correct answers	Wrong answers	Partially correct answers	Points awarded
1.	20	1		20
2.	19	2		19
3. (a)	19	2		19
3. (b)	17	4		17
4.	5	3	14	24
5.	7	11	3	17
6.	18	0	3	39
Total	**97**	**23**	**20**	**155/210**

Figure 13: Histogram of score distribution

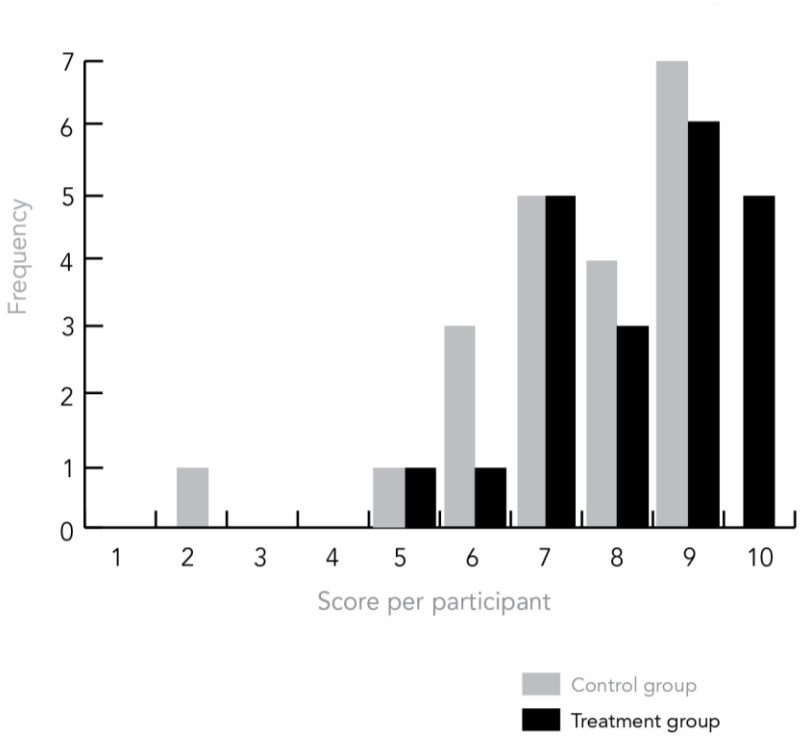
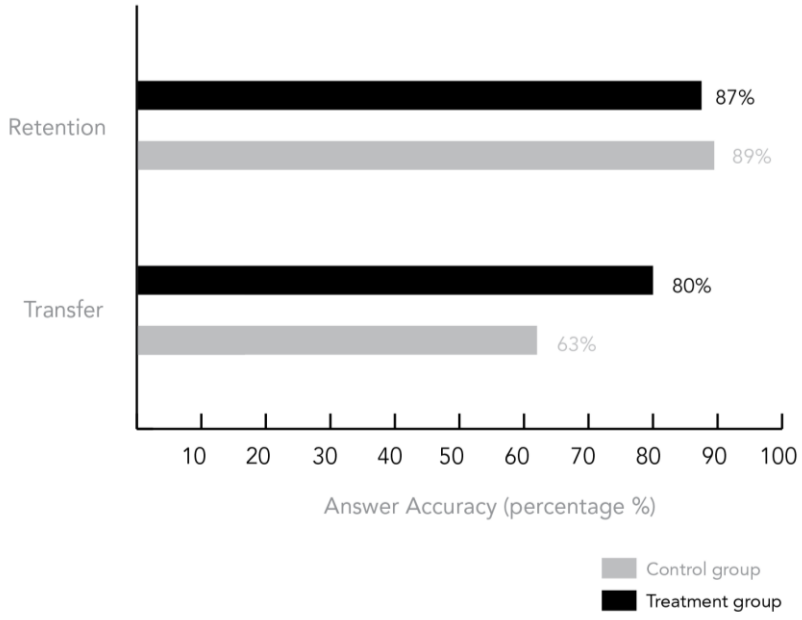


Figure 14: Retention and transfer performance

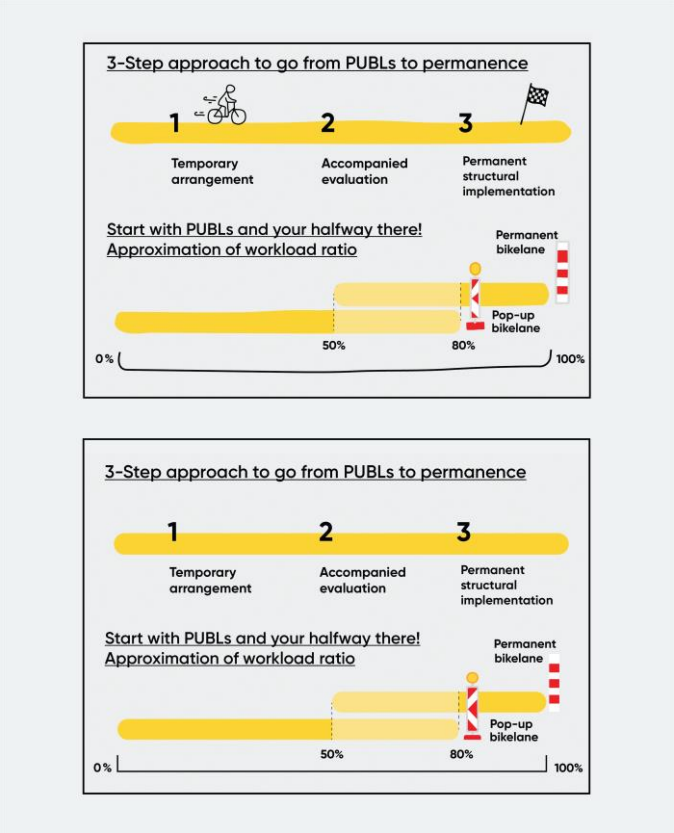


The treatment group was awarded the most points when comparing the treatment results and the control group. As depicted in Figures 11 and 12, the treatment group had 117 correct answers, 13 partially correct answers and 17 wrong answers. The group collected a total of 174 out of 210 points. In contrast, the control group had 97 correct answers, 20 partially correct answers and 23 wrong answers. In total, 155 points were awarded to the control group. Additionally, when looking at the histogram shown in Figures 13, it is possible to observe a difference in the scoring distribution. Five participants from the treatment group scored the full 10 points, whereas no participant from the control group scored the full ten points. Also, the participants from the control group scored the lowest three scores (2,5 and 6) more frequently. Based on the raw data, one can safely argue that the treatment group performed generally better than the control group. However, in order to ascertain the significance of this outperformance, it remains necessary to conduct statistical analysis of the collected data. This will be addressed later on in the paper.

Upon conducting a deeper evaluation of the data, additional observations were made. One obvious finding was that the treatment and control group had only a minor difference in performance when it came to retention questions. According to the data presented in Figure 14, the treatment group had an accuracy rate of 87% in providing correct answers, while the control group performed slightly better with an accuracy rate of 89%. However, on the transfer test, the treatment group performed better than the control group by a much greater margin. The treatment group achieved an 80% rate of correct answers, while the control group only achieved a 63% rate.

The disparity in performance on the transfer test is especially noticeable for questions 4 and 5. The treatment group performed better, with an 11-point and 7-point advantage, respectively. This is observable when comparing Figure 11 and 12. The reason for this outcome was that participants in the control group gave more partially correct answers, which frequently won them one point only. Compared to participants from the treatment group, who provided complete answers and thus were awarded two points more frequently.

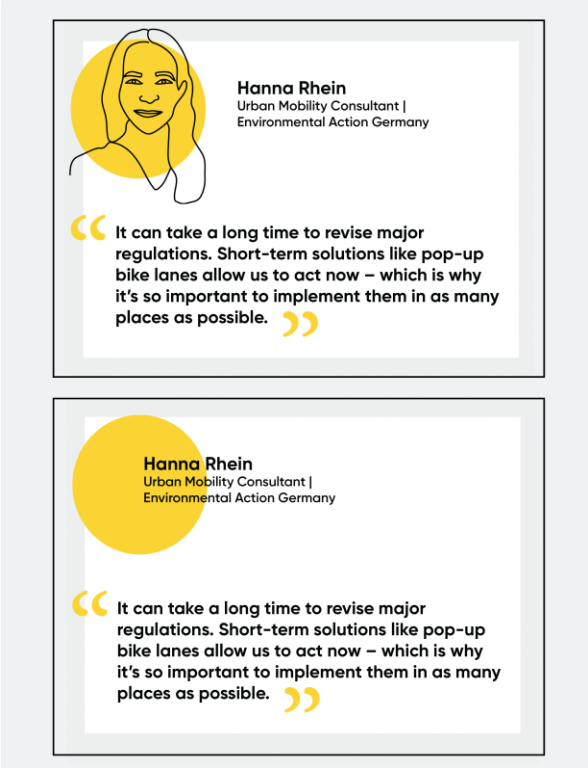
Figure 8: Visual prosody through the depiction of race to end goal. Hand-drawn vs computerised drawings can be observed in the depiction of the flowchart and the road barriers.



In the case of question 4, the answer was partly communicated through text and partly through the flowchart titled *3 steps approach from PUBLS to Permanence*. The flowchart was differentiated through the presence or absence of visual prosody and a human. As seen in Figure 8, participants from the treatment group received the flowchart with a person on a bicycle racing to the finish line on top of the flowchart bar. This feature was absent from the infographic used amongst participants from the control group. Since a part of the answer was also communicated through text communication, it is unclear how much influence the flowchart with visual prosody may have had on the participants' performance, especially when considering that the information provided by the flowchart was referenced with equal frequency by participants from both groups. Nine of the twenty-one treatment group participants and seven out of twenty-one control group participants made mention of the information from the flowchart in their answers. Therefore the impact of the feature, if present, must have been relatively small. Furthermore, since the text remained identical, it is challenging to pinpoint an exact explanation for this difference in performance when it comes to this particular question. A possible explanation is that

the treatment group participants might have generally been more motivated when reading the infographic and answering the questions considering that these participants referenced the information from text content in their answers more often. They showcased a more well-rounded understanding of the question in their answers by including both information from the text and flowchart. Hence, it is plausible to argue that the features encouraged them to read the text in a more in-depth manner. In that case, visual prosody and hand-drawn imagery can be understood as having an indirect impact that promotes engagement with other elements provided, which in this case was information presented in text form.

Figure 7: Presence vs absence of humans in the presentation of quotes



Regarding question 5, both groups performed relatively poorly compared to other questions. However, the treatment group still performed better by a margin of seven points. The answer to this question was communicated in two quotes and the main text. The participants had to apply extra effort by piecing the information together to provide a complete, correct answer. However, providing answers mentioned in the quotes would have awarded the participants at least one point. The difference in the quote presentation was the presence or absence of a face next to it, as shown in Figure 7. Apparently, adding faces to the quotes appeared to have made a difference

since only eight control group participants referenced the information from the quote compared to fifteen treatment participants who included the information in their answers. This is an interesting finding as it indicates that quotes have a greater impact when paired with faces. The finding is in line with previous research indicating that faces have the ability to attract attention more than other stimuli with less biological significance.[158,159] According to Theeuwes and van der Stigchel, faces have a significant impact on our attention because they have been a crucial social stimulus throughout evolution.[160] As a result, faces are prioritised during mental processes.[161] Based on the results and taking into account previous studies, there is strong evidence to believe that faces have the potential to improve engagement in multimedia-based learning. By first attracting the viewer's gaze to a specific locus, they may then increase the possibility of more viewer's engagement with the provided material. This, however, would require further testing in the multimedia field to be confirmed. Nonetheless, the result obtained provides a promising groundwork.

Figure 9: Visual prosody through the addition of traffic lights representing barriers and drives. Hand-drawn vs computerised drawings can be observed in the depiction of the icons and table columns and rows.

[158] Ro, Tony et al., "Changing faces: a detection advantage in the flicker paradigm." *Psychological science,* vol. 12, no.1, 2001, pp. 94-99. doi:10.1111/1467-9280.00317, pp. 94.
[159] Kapsetaki, Marianna E. & Zeki, Semir "Human Faces and Face-like Stimuli Are More Memorable." *PsyCh Journal*, vol. 11, no. 5, June 2022, pp. 715–19, doi:10.1002/pchj.564, pp. 715.
[160] Theeuwes, Jan, & van der Stigchel, Stefan, "Faces capture attention: Evidence from Inhibition-of-return." *Visual Cognition*, vol.13, no. 6, 2006, pp. 657-665, doi.org/10.1080/13506280500410949, pp. 657.
[161] Ibid.

It was also observed that visual prosody and hand drawn imagery did not always have a direct impact on viewer engagement. This is apparent when considering the one instance whereby the control group performed better than the treatment group. In this case, question three which was a retention question whereby the control group led by a total of four points. The answer to this question was derived from the information presented in the body text which was repeated once more in the table shown in Figure 9. The treatment group was presented with hand-drawn icons and traffic lights that acted as visual prosody in presenting barriers and drivers. This feature did not seem to have impacted the treatment group participants. On the contrary, if any impact were present, it would have been slightly negative in this particular instance. Therefore it should be noted that the addition of humans, hand-drawn drawings, and visual prosody did not prove beneficial or relevant in all cases.

5.5 Analysis

5.5.1 Why Mann-Whitney U Test?

To analyse the gathered data from the treatment and control group, the Mann-Whitney U Test was performed. The Mann-Whitney U Test was chosen in this case because of a skewed data distribution and the survey's small sample sizes (n=21). The advantage of this non-parametric test is that there is no obligation to normal data distribution, in contrast to the independent t-test, where this is a requirement. Instead of using the average as the parameter, the Mann-Whitney U Test uses the median to calculate the difference between the two groups.[162] The two requirements of the Mann-Whitney U Test are that the data allows ordinal scaling and that the two groups being compared originate from the same population.[163] These requirements were met in this study since the participant's individual scores could be scaled from best to least with a scoring system ranging from 0 (lowest) to 10 (highest). Also, all of the participants had a commonality as they possessed a university-level education. They also self-reported more or less the same level of knowledge on mobility and transportation.

[162] Nachar, Nadim. "The Mann-Whitney U: A Test for Assessing Whether Two Independent Samples Come from the Same Distribution", *Tutorials in Quantitative Methods for Psychology*, vol. 4(1), 2008, p. 13-20, pp.13.
[163] Ibid.

5.5.2 Carrying out the Mann-Whitney U Test

The first step was to rank both data sets together in ascending order from least to best performance. The data from the treatment group and that from the control group were assessed together, and each score was given a rank, as seen in Figure 15. With 42 data in total, the smallest score is allocated the first place on the rank and the largest score is allocated the last place on the rank. When there are multiple of the same score, the mean of the scores' rank is calculated and allocated to each score. At the end of this practice, the sum of the ranks for each group is calculated. See the table for the sum of ranks won by each group.

The next step was to calculate the U statistic for both the treatment and control groups. The following formulas demonstrate how U is calculated, with n being the sample size and having a value of 21 in each case. R represents the sum of ranks stemming from the prior calculation, with R_1 and R_2 being 519.5 and 383.5, respectively. In the case of U_1, a value of 152.5 was obtained by using data from the treatment group, while U_2 utilised data from the control group and obtained a value of 288.5. The smallest value between the two U stats becomes the U score, which in this case is 152.5. This U score is then used to calculate the z score from which the p-value is determined.

Figure 15: Sum of ranks of the treatment and control group

Treatment group	
Participants' individual score (out of 10)	Rank of score
5	2.5
6	5.5
7	12.5
7	12.5
7	12.5
7	12.5
7	12.5
8	21
8	21
8	21
9	31
9	31
9	31
9	31
9	31
9	31
10	40
10	40
10	40
10	40
10	40
Sum of ranks: 519.5	

Control group	
Participants' individual score (out of 10)	Rank of score
2	1
5	2.5
6	5.5
6	5.5
6	5.5
7	12.5
7	12.5
7	12.5
7	12.5
7	12.5
8	21
8	21
8	21
8	21
9	31
9	31
9	31
9	31
9	31
9	31
Sum of ranks: 383.5	

$$U_1 = n_1\, n_2 + \frac{n_1\,(n_1+1)}{2} - R_1 \qquad U_1 = 21.21 + \frac{21\,(21+1)}{2} - 519.5 = 152.5$$

$$U_2 = n_1\, n_2 + \frac{n_1\,(n_1+1)}{2} - R_2 \qquad U_2 = 21.21 + \frac{21\,(21+1)}{2} - 383.5 = 288.5$$

Prior to calculating the z score, a statistical threshold of 5% or 0.05 significance was determined, and the test was categorised as two-tailed since the alternative hypothesis did not predict any particular direction. The z score was then calculated using the following formula below with μ_U corresponding to the average of the U distribution and σ_U referring to the standard deviation of the U distribution.

$$= \frac{U - \mu_U}{\sigma_U} \qquad z = \frac{U - \frac{n_1.n_2}{2}}{\sqrt{\frac{n_1.n_2\,(n_1 + n_2 + 1)}{12}}}$$

$$z = \frac{152.5 - \frac{21.21}{2}}{\sqrt{\frac{21.21\ (21 + 21 + 1)}{12}}} = -1.71$$

The corresponding probability value from the z-score is **0.083541**. *At the significance level of p< 0.05, the p-value of 0.08 is considered not significant*. With this result, there was not enough evidence to support the alternative hypothesis H_1 and not enough evidence to reject the H_o hypothesis. To recall, the H_o states that participants with higher education provided with infographics with emotional design features, including human figures, drawings, and visual prosody, achieve the same learning outcomes as those provided with infographics without such features. The following chapter will present the interpretation and integration of the analysis results into the current research landscape concerning emotional design.

6 Discussion

In this section of the paper, a concise overview of the results is presented. These results are then interpreted in the context of the provided theoretical framework. Also discussed here are the study's shortcomings. In addition, the study's findings are examined for their theoretical and practical implications, and suggestions for future research are provided.

6.1 Results interpretation

This study aimed to analyse the influence of Holmes' criteria on learning and gain a deeper understanding of how these specific emotional design features affect people with high levels of education. One of the features, human presence, was categorised as an anthropomorphism which has proven to support learning in multiple instances. On the other hand, hand-drawn drawings and visual prosody lack extensive research to claim any major effect. Therefore, the study on the impact of these combined features on a particular niche audience provided a novice approach to the field of multimedia learning. In this study, the treatment group exposed to these features generally performed better than the control group. The group collected 174 points out of 210, whereas the control group scored less by 19 points, with a total of 155 points. In addition, the enhanced performance by the treatment group was observable when acknowledging the 5 participants that were able to score the full 10 points on the tests. This was not the case with the control group, where none of the participants scored the full 10 points. Moreover, it was evident that the control group had a lower performance based on the analysis of score distribution, as the participants in this group often had the lowest scores.

The more detailed analyses of the data led, however, to more complex observations. Participants from both groups had similar performances when it came to the retention test. In this case, the scores differed by a slight margin of one to three points. Therefore it is to be argued that the three Holmes' criteria used in this study did not impact retention performances among the participants. This was not the case when it came to transfer questions, whereby the treatment group performed better by a greater margin than the control group.

When it came to one particular transfer question, it was observed that the much lesser performance of the control group could not always be directly linked to variations in visual aids used for the questions, since the control group participants referred to the information from the visual aid as often as the treatment group participants did. In particular, nine of the twenty-one treatment group participants and seven out of twenty-one control group participants made mention of the information from the visualisation in their answers. Therefore it was argued that this difference in performance may have originated from an indirect impact of the features that encouraged the treatment group participants to experience a higher motivational level. This then allowed them to engage more with the information presented beyond just the visualisations, especially considering that they referenced the information from the text more frequently than the control group participants and therefore had an overall better transfer performance.

In another instance involving a transfer question, the improved performance could in fact be directly linked to the visual aid provided to the treatment group. They were presented with expert quotes accompanied by illustrations of their faces. These faces were absent in the infographic provided to the control group. Their presence appeared to have been impactful, considering that only eight control group participants made mention of the information from the quotes compared to fifteen treatment group participants who noted this information in their answers. This finding is intriguing since it implies that quotes are more memorable when combined with faces. It would be worthwhile for further research to explore the memorability of quotes when paired with human faces, given that past studies have shown that faces do attract more attention than artifactual stimuli. It has therefore been argued, on the basis of the results alongside previous studies, that the use of facial images should be taken into consideration in the attempt to attract more attention to particular information and, as a result, encourage more engagement in multimedia learning.

One final observation was related to the one occasion whereby the control group outperformed the treatment group. This was in the case of one retention question. The difference was by a narrow margin; however, this remains a valuable observation as the question was directly linked to a visualisation whereby hand-drawn icons and visual prosody were included and presented to the treatment group.

This particular case provides substantial evidence that the addition of hand-drawn drawings and visual prosody does not always enhance direct engagement. It appears to be that the impact of these features is limited in certain instances and should not be considered as promoting engagement regardless of context.

To investigate if the Holmes' criteria provided an added educational value to the infographic, a Mann-Whitney U Test was conducted. The U-Test compared the distribution of the median score of the two groups. At a significance level of 95% and a p-value of 0.08, no statistical difference could be observed between the performance of the two groups. Therefore lacking sufficient evidence to support the alternative hypothesis that predicts a significant difference between the learning outcomes of the two groups. It remains crucial to consider that the raw data and the relatively low p-value obtained from the U Test do indicate a tendency for better performance when these features are included. However, because of the relatively small sample size a strong statistical significance could not be identified from the data. The features therefore remained to be investigated in a larger size sample.

The findings of this study, therefore, reject these features to act as seductive details that harm learning performance.[164] They also do not seem to cause an expertise reversal effect among highly educated individuals.[165] Simultaneously, the study does not confirm a significant educational value. Nevertheless, it was able to show that there is a slightly higher learning performance when humans, drawings and visual prosody are included in infographics targeted at highly-educated individuals. In addition, it was noticeable that the impact of these features varies in different instances. It would eventually require a larger sample size and a variation of infographics to investigate their impact further.

6.2 Limitations

When considering the limitations of this study, the most prominent one is the use of a small sample size. As with all quantitative analyses, larger sample sizes promote a more reliable and representative statistical analysis. However, due to time constraints, a larger amount of participants was not possible in the case of this master thesis. The sample size is particularly limiting in this study since the

[164] Harp & Mayer, Richard, How Seductive Details Do Their Damage, pp.414.
[165] Kalyuga, Expertise Reversal Effect, 2011, pp. 155.

tendencies of the raw data suggest a possibility of statistical difference with a larger sample size.

A further limitation was that only one infographic was used in the study. Therefore, the possibility exists that the results obtained are influenced by factors particular to the infographic. An investigation with two to three infographics would have eliminated any unwanted factors provided by the infographic itself. Again due to time constraints, conducting a study with a series of infographics was not possible in this case either.

Another aspect to consider is the possibility of misrepresentation from self-reporting results provided by the participants regarding their knowledge of mobility and transportation. Although the participants were asked the questions about this matter only after providing context from reading the infographic, it is still unsure to what extent their subjective experiences and knowledge are comparable—especially considering the geographical difference between them since some were situated in Germany and others in the Seychelles.

A limitation that can be attributed to the nature of the questionnaire itself is that the retention and transfer tests were taken entirely online. It is possible that the participants accessed the infographic when they were unaware of the answers to the questions or that they misunderstood the instructions. Regardless, the limited control over the participants' behaviour creates uncertainty regarding whether their involvement aligned with the study's requirements.

6.3 Implications and Recommendations

The tendency to have a slightly higher learning performance when humans, drawings, and visual prosody are present in infographics has several significant implications. A theoretical implication is that future discussions and research must acknowledge their positive but limited effect on learning in certain cases and not dismiss them as inherently harmful. Furthermore, the study adds to the specific research niche of emotional design by testing underrepresented features, which include humour and hand-drawn illustrations. Researchers may use the findings of this study when considering future studies related to these least-research emotional design features. Regarding more practical implications, the study carefully

advocates including these emotional design features when designing infographics for highly educated people. Designers and educators should not expect a greater engagement solely based on these features. However, they are encouraged to use them if aiming for a slight improvement in engaging readers, especially when it comes to the presentation of quotes, whereby the presence of faces may attract more attention to the quotes and encourage readers to read them.

As previously stated, one important recommendation is to examine Holmes's criteria in a larger sample to understand the degree of their effects better and have a better representation for a more general audience. Furthermore, for future research, it would be insightful to examine other criteria laid out by Holmes. The combination of three of his criteria does show some positive results, which provides a strong argument for investigating other criteria as well. However, to gain a deeper understanding of which criteria are most effective or potentially harmful to learning, it would be beneficial to test them individually. This would also provide a more exact assessment of their impact because as identified in this study, his criteria did not appear to be as equally effective in all instances. Future studies may look into that for more insight. Also, by testing Holmes' criteria among different population groups, more insights may be won regarding their limitation in relation to specific audiences. This may be beneficial to designers when producing infographics that are user-specific. One final recommendation concerns the memorability of adding faces to quotes. The results of this study suggest that the feature had a positive impact. It is recommended that further testing be conducted to gain a deeper understanding of its effectiveness.

7 Conclusion and Reflection

In a world where the user is constantly bombarded with information, the infographic can be a great tool in the competition for the user's attention. However, when it comes to infographics, simply catching the viewer's eye is not enough. It is crucial that its presentation promotes reader engagement to communicate complex information effectively. In this scenario, implementing emotion-arousal techniques may prove beneficial. Research has shown that emotion and cognition are very much connected processes and that positive emotions foster learning, curiosity, and creative thought processes. These findings must be taken into consideration when examining strategies for effective communication through the use of infographics.

Emotional design in multimedia learning, although a relatively new field, has proven to be positively impactful to learning outcomes. On this premise, this study looked at how Nigel Holmes' joyful approach may contribute to creating engaging infographics. Holmes argues that even scientists as readers may benefit from infographics designed in this manner. This thesis investigated these claims through a comparative survey with highly-educated participants whereby the treatment group was exposed to three of Holmes' nine criteria. In contrast, the control group was presented with an identical infographic without Holmes' criteria. Based on the data obtained, a better performance by the treatment group participant was observed. The elevated performance was apparent during the transfer test, whereby the disparity of scores was high. On the other hand, there was no noteworthy distinction between the scores on the retention test, as they displayed only minor variations.

Adding humans, hand-drawn drawings and visual prosody to visualisations did not necessarily prove advantageous or necessary in all cases. On one occasion, whereby the question was closely related to a visual aid, the control group managed to score higher than the treatment group. Another instance whereby the features had less of a direct effect was when the treatment group won more points by a high margin, and the result could not be traced back to the visualisation pertaining to this question. A possible explanation set forth was that the Holmes' criteria might have indirectly motivated the treatment group participants to engage deeper with the text information since they referenced the information from the text more frequently than the control group participants. The one particular case where one of the

features appeared to have a greater direct effect was when humans, particularly faces, were added to quotes. The treatment group participants referenced the information from the quotes more frequently and therefore performed considerably better than the control group on one of the questions. Based on prior research and repeated confirmation from this study, the use of faces was recommended as a design strategy to improve engagement in multimedia learning.

Even though the treatment group showed better performance than the control group, it was not considered statistically significant according to a Mann-Whitney U-Test. Hence, it is important to note that this enhancement should not be exaggerated to the extent of arguing them to be of educational value in an infographic. Simultaneously, it does remain imperative to consider the improved performance. On that note, infographic designers should not hesitate to incorporate emotional design elements to augment the chances for greater reader engagement. For future research, examining Holmes' criteria in larger sample sizes would be beneficial for greater statistical accuracy and higher representational value. Other Holmes' criteria not included in the study should be tested as well and with other demographics for a greater understanding of their benefits and limitations.

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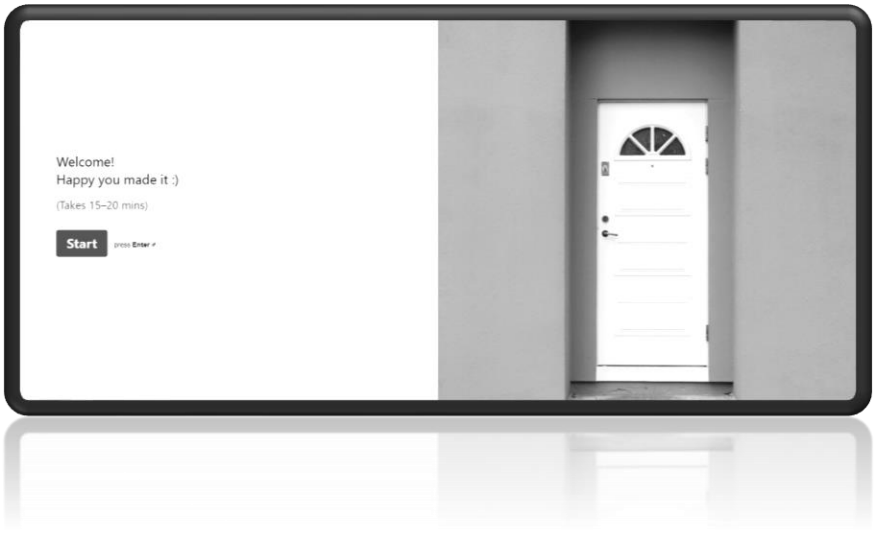
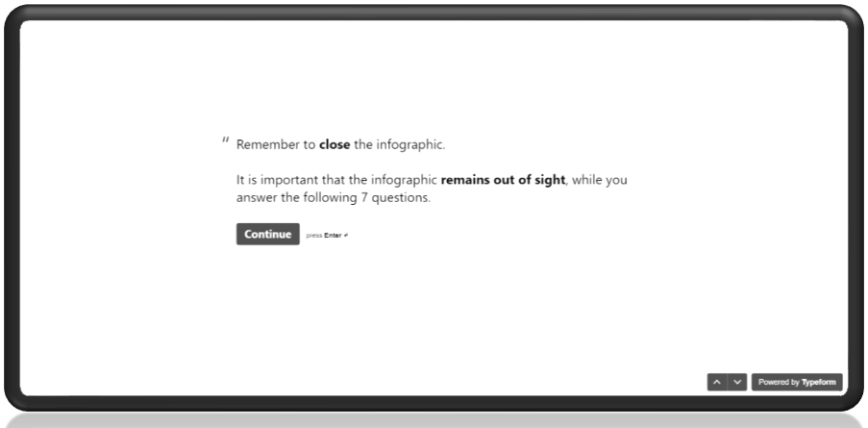
10. Table of Figures

11. Appendices

11.1 Appendix A: Survey




Remember to **close** the infographic.
It is important that the infographic **remains out of sight**, while you answer the following 7 questions.
Continue
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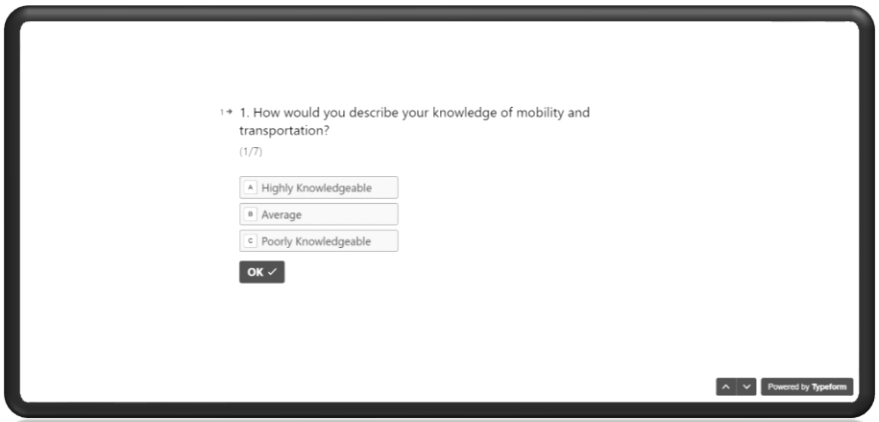
Powered by Typeform


1 → 1. How would you describe your knowledge of mobility and transportation?
(1/7)
A Highly Knowledgeable
B Average
C Poorly Knowledgeable
OK
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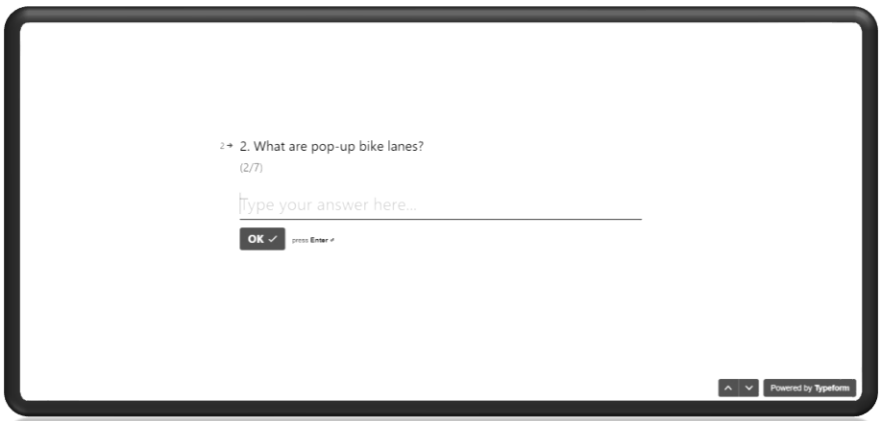
2 → 2. What are pop-up bike lanes?
(2/7)
Type your answer here...
OK
press Enter
Powered by Typeform


3 → 3. In which city were they installed?
(3/7)
Type your answer here...
OK ✓
press Enter
Powered by Typeform


4 → 4. Name one barrier and one driver in the process of installing pop-up bike lanes
(4/7)
Continue
press Enter
Powered by Typeform


4 → 4. Name one barrier and one driver in the process of ...
a Name a barrier
Type your answer here...
OK ✓
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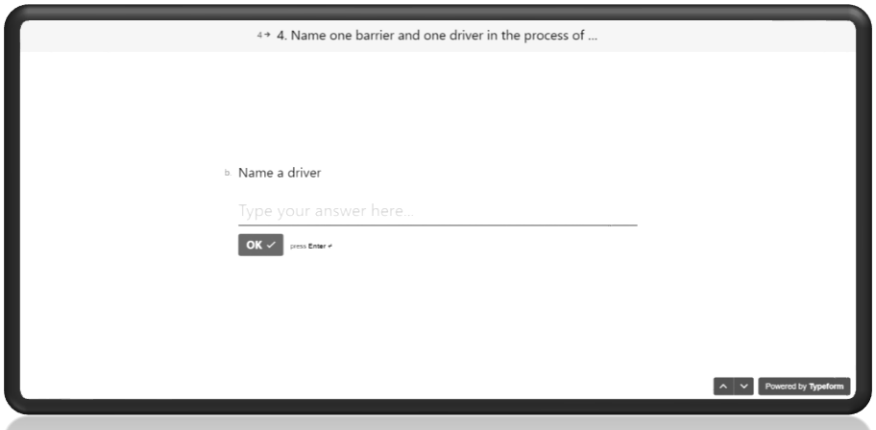
4→ 4. Name one barrier and one driver in the process of ...
b. Name a driver
Type your answer here...
OK ✓
press Enter ↵
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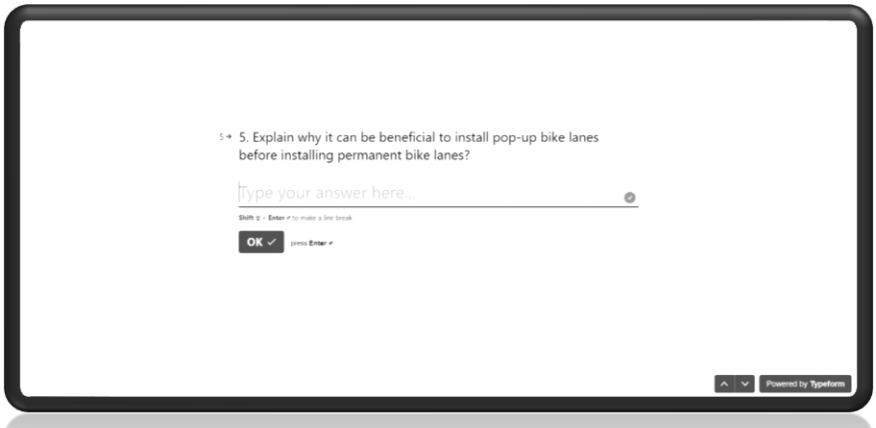
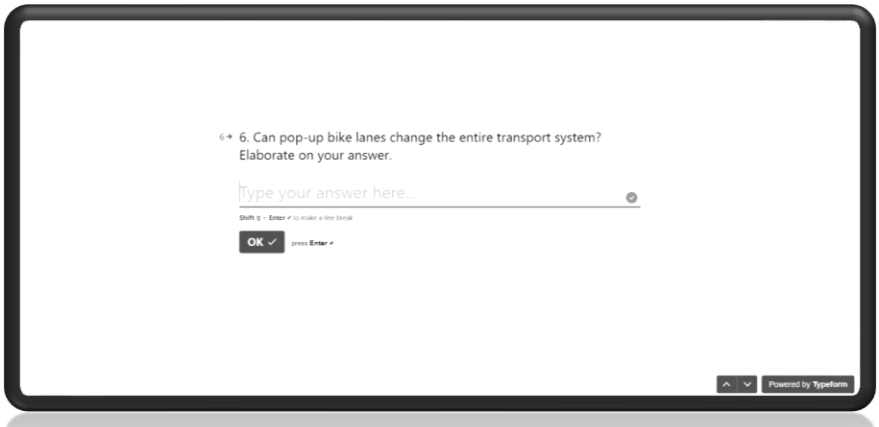

5→ 5. Explain why it can be beneficial to install pop-up bike lanes before installing permanent bike lanes?
Type your answer here...
Shift ⇧ + Enter ↵ to make a line break
OK ✓
press Enter ↵
Powered by Typeform


6→ 6. Can pop-up bike lanes change the entire transport system? Elaborate on your answer.
Type your answer here...
Shift ⇧ + Enter ↵ to make a line break
OK ✓
press Enter ↵
Powered by Typeform


7 → 7. How can bike lanes, in general, be beneficial in urban areas?
Type your answer here...
Shift ⇧ + Enter ↵ to make a line break
Submit
press Ctrl + Enter ↵
Never submit passwords! - Report abuse
Powered by Typeform


You made it to the end!
Thank you for participating.
Create a typeform
press Enter ↵

g Biketopia

ermanent: a case study on Berlin

One Health Research Centre · Therme One Health

Research question:

"What are barriers and drivers for the implementation of PUBLs and on which legal basis is it possible to steady this healthy and climate friendly mobility solution in post-COVID-19 times?"[1]

What are

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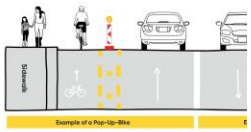
Road transition: from PUBLs to permanent



Friedrichshain-Kreuzberg, Berlin

The district is one of twelve districts in Berlin and was the first to implement this temporary solution, which quickly attracted national press attention.

20.4 km²

289,000 inhabitants

38 average age

> 25 km PUBLs steadied

Why pop-ups?
Start simple and move fast

Cycling is key to achieving healthy, climate-friendly mobility in cities. Although they have not yet had a major effect, PUBLs (pop-up bike lanes) have been shown to contribute to this vision. After PUBLs and the accompanying infrastructure were installed in Berlin, there was indeed an uptick in the use of bicycles.[2] But why start with pop-ups and not go straight for permanent bike lanes? Well, the pop-up approach allows a quick start in terms of the planning and deployment of bike lanes. **It's a much faster process than setting up permanent bike lanes. Furthermore, PUBLs are relatively cheaper, making them even more attractive.** For comparison, the installation costs for PUBLs in Berlin were approximately 10,000 euros per kilometre,[3] while planning costs alone for one kilometre of permanent bicycle lane in Berlin are usually around 40,000 euros[4].

Christian Haegele
Head of the Department for Traffic Management | Senate Department for Environment, Mobility, Consumer and Climate Protection, Berlin

"A pop-up bike lane is an example of a small step with a big impact. Pop-up bike lanes can't transform the entire transport system on their own, but they can play a valuable role in transition strategies in certain areas."

Ready, set, go!
Drivers for the implementation of PUBLs

The global **COVID-19 pandemic created a window of opportunity** for the establishment of PUBLs.[5] However, the administrative orders establishing PUBLs remained legally subject to German federal traffic law which is strictly road safety-oriented. Only traffic-related legal considerations and not the pandemic were taken into account as valid arguments by courts.[6] Instead of being a formal justification, the pandemic rather simply provided a catalyst for the establishment of PUBLs. The case of PUBLs in Berlin also shows that **close cooperation between different levels of public administrations, partly thanks to established connections between important decision-makers, was crucial for success** – a good example is the cooperation between the Department of Traffic Management and the Department for streets and green spaces in the District Office of Friedrichshain-Kreuzberg.[7] Other notable drivers included the **perseverance of the relevant administration as well as the personal commitment of individuals** in management positions. This is even more effective when bicycle infrastructure is embedded in an overall bicycle planning concept.[8] Add strategies such as a bold interpretation of the applicable legal framework and doing the most with the resources at hand, and PUBLs can play a major role in bringing the mobility transition to life.

Avoiding the pitfalls
Barriers to the implementation of PUBLs

Obstacles to the deployment of PUBLs mainly mirror the above stated drivers. These solutions are **mainly held back by a lack of personal commitment in public administration.** This inactivity[9] can be attributed to political attitudes, differing priorities or a lack of courage or knowledge in interpreting legal frameworks.[10] In some situations, when one or more of these barriers have been present at the same time within a given administration, it has been impossible to implement these temporary solutions. Other obstacles **spring from outdated administrative structures and principles of traffic planning, such as a – perhaps typically German – excessive administrative meticulousness**, as well as the unexamined but pervasive idea that nothing must get in the way of smoothly flowing car traffic.[11] Other possible issues include a lack of participation by citizens and inadequate transparency on the part of the administration, which may lead to dissatisfaction and rejection among important stakeholders.[12] Finally, interviews have shown that **a lack of resources – whether in terms of personnel, finances, or time – has been one of the main obstacles** to the expansion of PUBLs.[13]

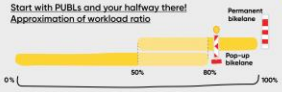
Here to stay!
Steadying temporary solutions

Making PUBLs permanent means expanding this solution that is originally designed to be temporary with permanent fixed infrastructure – for instance, changing the temporary spatial demarcation by dellineators to a permanent spatial demarcation by bollards. In Friedrichshain-Kreuzberg, for instance nearly all PUBLs have been thus changed to permanent bike lanes.[14] **In general, a three-step approach seems to prove successful and was thus presented as a possible future standard procedure: 1) temporary arrangement, 2) accompanying evaluation and 3) permanent structural implementation.**[15] Such a course could be followed by other cities in Germany and elsewhere, building on the notion that showcasing best practices can be a great way to ensure that PUBLs are made permanent.

The formal evaluation between temporary and permanent makes it possible to refine planning guidelines based on identified improvement needs, thus shortening planning procedures considerably.[16] Experts opinions regarding the ratio of the effort to implement a PUBL and make it a permanent solution afterwards ranges between 80% (temporary) / 20% (steadying)[17] to 50% / 50%.[18] This reduces planning costs and financial barriers when implementing biking infrastructure.

3-Step approach to go from PUBLs to permanence

Start with PUBLs and your halfway there!
Approximation of workload ratio



Finding Biketopi
How do we get

PUBLs prove that fast, efficient
gally sound action that can boost
mobility and provide climate-
solutions is possible. So what's n
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give municipalities greater scope fo
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and regulations, as well as provi
with more resources.[19] **Most impo**
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Drivers	Barriers
Personally committed leaders	Reluctant administration
Good cooperation on administrative levels	Old administrative structures & ideologies
Window of opportunity (COVID-19)	Lack of resources

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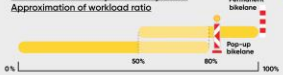

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Hanna Rhein
Urban Mobility Co
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Sources