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Research Article

The Research into Dark Mode: A Systematic Review Using Two-Stage Approach and S-O-R Framework

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Abstract:

Many company owners are taking notice of the popularity of dark mode in mobile apps, and many users are opting to utilize it for various reasons. There haven't been many comprehensive studies on the idea of dark mode or its definition, therefore it is still a relatively new area of study in academia. To add insult to injury, academic conclusions on ongoing investigations and forthcoming developments in the dark mode are few. Many people still disagree on the benefits and drawbacks of dark mode. To fill this void, this paper reviewed the literature on dark mode from a variety of academic fields. Its goal was to lay the groundwork for future research on the topic of dark mode and user experience by developing a basic research methodology for studying the two together. This report used a two-step process based on the Scopus database to search for and gather papers about dark mode research over the last 30 years. After reviewing all of the papers, 35 met the inclusion and exclusion criteria. Dark mode's topics, background, theoretical underpinnings, and research methodologies were first examined in this work. Then, using the "Stimulus-Organism-Response (S-O-R)" paradigm, it categorized and combined the dark mode study variables. In the end, it suggested a study methodology that would explain the deeper meaning of dark mode and the connection between user behavior, their experience, and many variables. This work went above and above by outlining possible avenues for future dark mode research and pointing out where present document studies are lacking.

1. Introduction

In information technology and business, "dark mode" is a display technique that modifies the screen interface to enhance viewing comfort in low-light conditions, using a dark color scheme with white lettering [1]. For the first displays, the sole available display mode was dark mode, which had green, amber, or white text on a black background. According to corresponding studies, those with visual impairments who are looking to reduce visual tiredness may benefit from using dark mode [2,3]. The claim that turning on dark mode on a phone helps conserve energy is true [4]. Contemporary youth trendily embrace dark mode on their electronic gadgets to cultivate a stylish and appealing aesthetic. The use of "dark mode" is more prevalent in everyday life, significantly affecting business and society [5]. As shown above, although some academics have investigated "dark mode", there has been little focus on its professional and academic examination [6] Currently, there exists neither a framework for research on "dark mode" nor a comprehensive review including the ideas, theoretical foundations, methodologies, and outcomes of previous studies on "dark mode" and there is much dispute around the findings of various studies [5,7,8,9]. Moreover, the notion of "dark

mode" is often used in commercial contexts, hindering individuals from grasping the academic principles and associated theories of "dark mode" [10]. This means that concepts, experiences for users, technological systems, and commercial areas all require a consistent framework to describe the "dark mode". A thorough and organized summary of previous studies on "dark mode" is presented in this work. It dissects the chosen body of literature, looking carefully at each publication's definition, conceptual foundations, research methodology, and historical backdrop of "dark mode", among other things. In order to facilitate future studies on the effects of the "dark mode" on humans, this study aims to get a deeper comprehension of it and incorporate current studies into a comprehensive academic research framework. The results provide light on "dark mode" and its user experience by reviewing current empirical studies in an organized manner. They also highlight the best ways to examine "dark mode"'s attributes and user interface. Here is the paper's structure: To begin, the term "dark mode" and notions associated with it are defined; Second, we examine 35 research publications that passed our screening process and detail the steps we used to find relevant material. A research framework to discover and integrate elements linked to "dark mode" and its user experience has been built using the "S-O-R theory" and data from these articles. The framework may be utilized as a systematic study procedure. Lastly, the article delves into the study's practical and theoretical contributions, touching on areas such as future research objectives and prospects for "dark mode".

2. Definitions of "Dark Mode" and Related Concepts

A computer program option known as "dark mode" may be used to make the UI darker. The backgrounds go from light to dark while text goes from dark to light. The end product is an interface that seems to be inverted and is mostly decorated with dark tones [11]. According to certain tech sector design professionals, "dark mode" is a color style and trend characterized by the usage of mostly dark colors, as seen through the lens of hue theory. As Hoober (2020) points out, this aesthetic is in line with the most common default interface style, which relies heavily on pastel colors [12]. In system design for user interfaces, "dark mode" means a color scheme or program that instantly alters colors to safeguard users' eyes from harmful UV rays and make staring at screens for long periods of time more comfortable (Figure 1). Academically, "dark mode" first denotes a screen display technology and design.

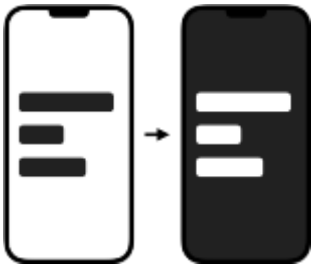

Figure 1. *The comparison of the interface between dark and light mode*

The visual impacts of bright text and information on a dark backdrop are referred to as "negative display polarity" or "negative contrasting polarity" [6]. This article examines the notion of "dark mode", which emerged as a trend in business in 2019. It references definitions from academic literature and incorporates terminologies from the legitimate commercial sector to broaden the comprehension of "dark mode" [13,14]. These search terms include ideas intimately associated with "dark mode" (Table 1).

3. Research Methodology

3.1 Methodological Overview

In order to include the prior studies on "dark mode" and its user experience, a two-stage method was used to search and filter the previous studies. The two-stage method, first suggested by Heckman (1979) to detect and reduce the effects of possible sample selection bias, comprises two successively applied phases [25]. Two steps are necessary to ensure the reliability of the results: first, selecting appropriate samples; and second, reducing bias in the selection process and honing down on the most important variables [25, 26]. In subsequent years, this method found extensive use in academic research as a powerful tool for changing samples to get fundamental data and build research models. Hence, this article is well-suited to the two-stage method [27,28]. To make sure we don't overlook any pertinent study material, we use a number of related keywords throughout the search process, as the "dark mode" lacks a cohesive academic idea and keywords. In addition, the two-step method may find papers that have used various keywords to describe the same study subject [29,30]. According to Klyver, Steffens, and Lomberg (2020) and Tapia-Muñoz et al. (2022), this technique enables us to collect a substantial amount of data in the initial stage, and then in the second stage, by limiting the variables that are fundamental to the research [31,32], we can eliminate data that is not pertinent to the topic.

Table1. *Definition of "dark mode" and its related concepts*

Concept	Definition	Reference
"Dark mode"	"Dark mode" is a software feature for mobile applications and websites that obscures the user interface. It alters gadgets and programs that traditionally include an appealing backdrop, ranging from gray to black.	[11,15,16]
Black mode	Black mode is a technological feature that has a significant impact on the user's experience. Its intellectual foundations are based on the notion of minimizing screen-emitted light. Historically, the constraints of the cathode ray tube technology necessitated the use of a "black mode" in early computer displays.	[10]
Dark theme	A dark theme is a UI style that uses mostly black surfaces and has low-light capabilities. In most user interactions, the dark theme shows dark surfaces. Its purpose is to serve as an auxiliary mode that enhances the standard or light theme.	[10,17,18]
Night mode	"dark mode" and Night Mode have many of the same functional goals and approaches, such as using bright content on dark backdrops to alleviate eye strain. While "dark mode" is usable at any time of day, it is most suited for usage at nighttime. In "dark mode", the UI backdrop is a deeper shade of black, while in the nighttime mode, the screen's color temperature is adjusted to a warmer one.	[1, 11]
Light mode	When you turn on most gadgets, such as smartphones and laptops, the interface will automatically go to light mode. To create the illusion of writing with ink on paper, this setup uses black or dark text on top of a white or light-colored screen.	[19-21]
Light-on-dark	The light-on-dark color scheme was first developed for use in computerized user interface photographs on CRTs and has dark backgrounds with bright letters.	[19]
Positive display polarity	The display's polarities are a representation of the several ways in which light and dark are presented. Letters with a bright backdrop and black letters indicate positive polarity.	[6,22]
Negative display polarity	A negative polarity symbol is a glowing dot on a black backdrop.	[6,22]
Positive contrast polarity (light mode)	To emphasize how different, the text is from the background, the term "contrast polarity" is used. The term "light mode" or positive contrast polarity describes how dark-hued fonts seem when displayed against a light backdrop.	[9,23]
Negative contrast polarity ("dark mode")	By showing white text on a black backdrop, negative contrast polarity, often called "dark mode", is created.	[9, 23]
Positive text-background polarity	The negative contrast or positive side of the text-background relationship is often used to describe dark characters displayed against a glowing backdrop. This is because the Michaelson contradiction c ¼ (Lt7Lb)/(Lt þ Lb) gets antagonistic when the text's brightness (Lt) is smaller compared to the background's brightness (Lb).	[24]

This methodology provides a solid foundation for developing a variable-centered model. The first phase in this paper's methodology was to find relevant articles in the target database by conducting a keyword search in "dark mode". Then, to eliminate any ambiguous or non-target articles, the second step involved setting particular requirements and limiting the scope to further screen the initial collection (Figure 2 shows the literature checking and testing process). In order to analyze and summarize the results in a quantitative and unbiased manner, we next classified and categorized all of the data using the matrix technique of literature review [33] suggested. The "S-O-R theory", which was covered in Part 5, was used to build a framework for study on "dark mode" user interfaces.

3.2 Study Design and Data Collection

There have been no targeted investigations on "dark mode," as mentioned in the introductory section of the literature review. For this work, the data needed to complete the research were found in The Scopus database. Scholarly material on a wide range of topics is available in Scopus, the biggest peer-reviewed abstract citation index in the world. These topics include medicine, the social sciences, engineering, technology, art, and the humanities, among many others. Additionally, it has included a large number of books, journals, and articles.

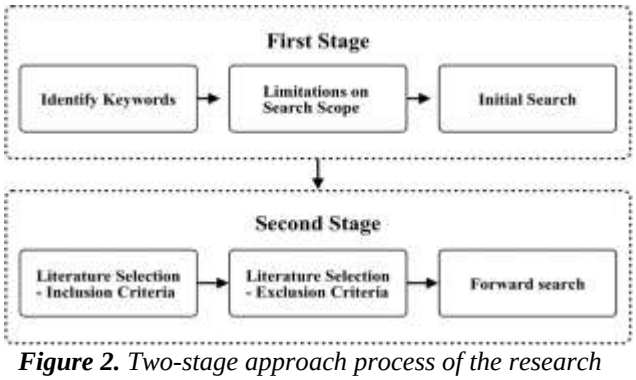

Figure 2. *Two-stage approach process of the research*

According to Morschheuser, Hamari, Koivisto, and Maedche (2017), searching Scopus will provide comprehensiveness, dependability, and high-quality data while keeping algorithm and function execution consistent [34]. In terms of the time frame for the research and searches, Dillon's 1992 critical review offered the theoretical definition of the "dark mode" in the existing literature [14]. Since we are interested in learning about empirical studies on the term once it has been defined academically, the research and searches for this paper will take place between 1992 and 2022. Given the synonyms for "dark mode" noted in the table above, the database search used generic and basic phrases that may be used interchangeably for the particular issue. These terms included "dark mode," "black mode," and "dark theme". Consequently, 143,386 publications published between 1992 and 2022 were retrieved, all of which were linked to the study issue. The purpose of this study is, therefore, to learn more about dark mode and how it works for users. Thus, empirical investigations on dark pattern technology including human elements or sceneries from human life were a part of the initial stage. Information technology, the social and natural sciences, the arts and humanities, nursing, health care, and the social and natural sciences were the primary search terms for relevant literature on "dark mode" and user experience. Also, in an attempt to limit biases and boost the information's dependability, the literature may only be of the "Journal Article" or "Conference Paper" types. Accordingly, 26,350 publications were screened using these 11 search terms. The inclusion was grounded on the following criteria (Table 2 and Table 3): Ultimately, by consolidating search results for 11 keywords and eliminating duplicate items, 35 papers and articles were identified. Subsequently, we performed a lookahead search using these 35 articles to ascertain the presence of any omitted papers based on their pertinent citations. We discovered no missing documents after a thorough preliminary examination. Data was gathered from 35 articles about the following aspects: (a) bibliometric details (including author, publication date, academic field, etc.), (b) study subject, (c) research technique, (d) theoretical framework, and (e) study sample. The chosen literature was then classified and examined using the matrix technique of literature review outlined in the study methodology. A review was ultimately compiled on the topics, context, research methodologies, theoretical frameworks, and research trends within the "dark mode" domain.

4. Results

4.1 Overall Research and Publications

This report provides a comprehensive assessment of the bibliometric data from 35 included studies. Figure 3 illustrates the papers about "dark mode" from 1992 to 2022. Despite the first academic description of "dark mode" emerging in 1992, it has not garnered much interest from scholars after that time. The chart illustrates that empirical study on "dark mode" began in 2005, after a 30-year period. The name "polarity display technique" was debated and used in place of "dark mode" [35]. Subsequently, "dark mode" started its integration into the academic sphere. Nevertheless, the volume of published material has been limited and has a convoluted trajectory, peaking in 2021. Following a decrease in publications from 2017 to 2018, there was an increase in 2019, maybe linked to the extensive introduction of "dark mode" by Apple and Android that year. Figure 4 illustrates the quantity of academic research articles about "dark mode". Computer Science rated highest with 12 publications, followed by Health Professions with 11 publications, and Engineering & Technology with 7 publications, demonstrating that research on "dark mode" mostly pertains to computer technology.

Table 2. *Criteria for literature selection*

Criteria	Inclusion	Exclusion
Study focus	Studies focused on "dark mode" techniques or closely related subjects.	Studies where the topic is unrelated to "dark mode" or does not focus on "dark mode" techniques.
Definition of "dark mode"	Articles that clearly define and adhere to the concept of "dark mode".	Articles where the definition of "dark mode" is ambiguous, contradictory, or inconsistent with its actual meaning.
Relevance to screen display	Academic research specifically related to "dark mode" screen display technology.	Studies unrelated to "dark mode" screen display technology or focused on other unrelated screen technologies.
Selected articles	A total of 73 relevant articles were identified, screened based on subject, abstract, and keywords, and exported in text format.	Articles that did not pass the inclusion criteria for subject, abstract, or keywords.
Screening data	Detailed screening data for each term is shown in Figure 2.	Data or articles that were incomplete, irrelevant, or failed to meet the inclusion criteria.

Table 3. *The search results of keywords*

Keywords	Number of Initial Searches	Stage 1 Screening	Stage 2 Screening
dark mode	11030	1373	12
Black mode	14480	2405	0
Dark theme	1040	712	1
Night mode	4197	1088	3
Light mode	110307	20429	4
Light-on-dark	116	27	4
Positive display polarity	321	55	19
Negative display polarity	338	62	13
Positive contrast polarity	779	85	8
Negative contrast polarity	774	111	7
Positive text-background polarity	4	3	2

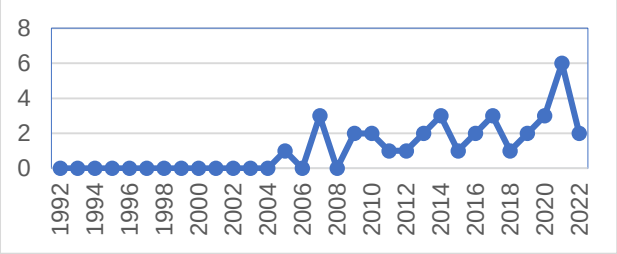

Figure 3. *Publications related to "dark mode" between 1992 and 2022*

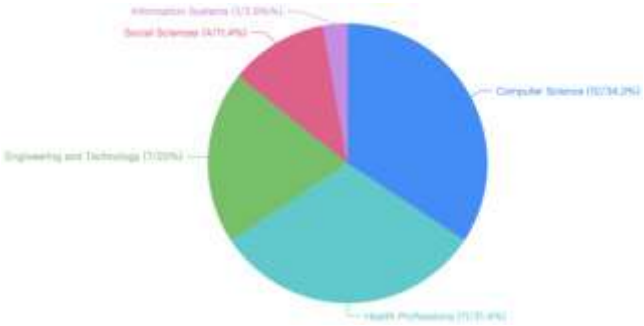

Figure 4. *Quantity of publications related to "dark mode"*

4.2 Methods in the "Dark Mode" research

The "dark mode" study has made use of a variety of approaches, as shown in Table 4. These include experiments, surveys, interviews, and more. Although eleven papers relied on a single experimental technique, twenty-four articles used a mixed-method design, mostly combining surveys with experiments. In twenty-one trials, this combination was used. Due to its foundation in both mixed and solitary research approaches, experiments have largely taken centre stage as the go-to research tool. Scientists conducted experiments to study how users' visual perception changes in "dark mode" [9] and how users' proofreading effectiveness is affected by pupillary alterations in "dark mode" [36]. In an effort to improve the assessment of user experience, researchers have conducted surveys and experiments to look at objectively unobservable data produced from experimental results. Using virtual reality head-mounted displays (HMDs), they measured users' eye movement activity and degrees of weariness, and they evaluated the efficacy of "dark mode" using short UEQ-S surveys. Additionally, Piepenbrock, Mayr, and Buchner (2014b) noted that some researchers used text experiments to measure users' reading efficiency and proofreading skills in "dark mode," and then used surveys to analyse users' personal experiences with "dark mode" during proofreading tasks [37].

4.3 Theories Involved in the "Dark Mode" Research

The following is a synthesis of the theoretical or research frameworks employed in the thirty-one chosen papers on "dark mode" (Table 5). As assessed, it is possible to identify that the majority of the papers do not presuppose any theory or framework. However, just a handful of literature theories have been mentioned as the rationale for explaining some of the concepts or as casual mentions without further elaborations. For instance, the term 'Ego depletion theory' forms the theoretical framework to explain that the "dark mode" enhances the 'honesty' in users. 'Gestalt psychology' is chosen to explain how the "dark mode" is related to the light mode as a negative polarity display and a positive polarity one. Notably, the UEQ theory and

Table 4. *Overview of research methods in the "dark mode" literature*

Research Methods	Total	Reference
Experiment	10	[3,8,9,24,36,38-42]
Questionnaire	1	[43]
Experiment & Case study	1	[44]
Experiment & Interview	2	[5]
Experiment & Questionnaire	20	[1,7,19,22,23,35,37,44-56]
Experiment & Questionnaire & Interview	1	[13,57]

Table 5. *Overview of research theories in the "dark mode" literature*

Related Theories	Definition	Reference
Ego depletion theory	According to ego depletion theory, the regulatory capacity of the participants is aroused when they are engaged in the self-control task and then unable to bring the same degree of it to other self-control tasks, therefore, they are likely to perform poorly.	[20,58,59]
Signal processing theory	Aside from proportion of spread and sum of two luminance levels of signal processing theory, the differences in these two positive and negative contrast Screen displays are also described.	[1, 60]
UEQ	The UEQ is basically a theoretical framework which gauges the user experience in six unique categories and includes the 'Attractiveness'. The results of the UEO may have some relation to the quality of the product based on its usage by users.	[3,50,61,62]
Gestalt psychology	A negative polarity display means that the colours of texts and backgrounds contrast each other. In the field of Gestalt psychology, this process of visual discrimination is termed figure-ground perception. In that case, the brightness of the text is then closer to its surroundings and seems to be 'confined' by the dark background as if the text is just overlaying the dark background.	[45,63]

its framework were used in two different papers to evaluate the questionnaire for assessing the usability [3] and subjective preferences [50] of "dark mode". In this paper, the "Signal processing theory" is pertinent in understanding the relationship between positive and negative polarity as well as light and "dark modes" as highlighted by Erickson et al. (2021) [19].

4.4 Samples for "Dark Mode" Research

Table 6 presents a summary of the samples employed in the "dark mode" research aggregate. The thirteen papers specify that the participants must be above eighteen years, while there is no limitation on the sources of the sample. Among the twelve papers that selected this type of sample, university students are the most preferred. Six papers are comparative studies of two different subjects, and four of them include both youth and the elderly, while the other two selected the students and specializing teams. Specifically, two articles carried out the trials on those gadgets instead of people, and one other paper offered no limitations regarding the subjects. The studies that had university students as subjects assumed that this group of users was more familiar with how the "dark mode" functioned (increase in contrast etc.) [5]. Researchers selecting the elderly samples were aimed at testing the hypothesis that elderly users will receive benefits from the display environment in "dark mode" [51]. Cross-sectional studies involving young and elderly people in order to determine whether the "dark mode" would affect them in the same way when they were both subjected to the same conditions [22]. Investigators with two samples of students and professionals wish to conduct an experiment free from bias while collecting solid data and information from professional employees and common clients. [57].

Table 6. *Study sample and proportions*

Study Sample	Number of articles	Total percentage
University students	12	34.3%
Staff	1	2.9%
Youth & Elderly	4	11.4%
Student & Specialist	2	5.7%
No restriction on sample sources above 18 years old	13	37.1%
No restriction on age or source of sample	1	2.9%
Non-human subjects	2	5.7%

5. Ordering Structure for "Dark Mode"

The study data and the "S-O-R theory" have been combined to form a new research framework that will hopefully lead to further studies on the "dark mode"'s" technology, features, content, and user behaviour. It may theoretically enhance the study and research of user experience processes related to information technology and goods [64]. The theory examines fundamental components of the user's experience and behaviour: perceptual-affective aspects regarding the objective emotions elicited by the environment and products [65], alongside cognitive-behavioral interactions encompassing learning capacity, comprehension skills, and physiological responses [66]. Therefore, the "S-O-R theory" is relevant for analysing the components and their interactions with "dark mode" and user

experience. Furthermore, it has been widely used for forecasting user behaviour in the realm of information technology [67]. This multi-mediated approach has effectively shown the relationship between the changeable system of "dark mode" and user experience in this study. The theoretical framework includes "stimulus," "organism," and "response." In this context, the "Stimulus" refers to the signals, specifically in this study, about the internal and external qualities. Consequently, all factors pertaining to "dark mode" have been discovered and categorised into pertinent categories for the examination of probable interrelationships, based on "S-O-R theory". I must highlight the definition of "Organism," which pertains to the impact of "dark mode" on the user; "Response" refers to the user's response after the experience of "dark mode." The study approach for user experience in "dark mode" is as follows: Consequently, identifying internal and external aspects of the "dark mode" as stimuli, it can be concluded that the employment of "dark mode" exerts cognitive, perceptual, as well as physiological effects on users, resulting in either a favourable or negative inclination towards its use. Consequently, the "S-O-R theory" may be used as an experience framework to enhance comprehension of "dark mode" users and elucidate their behaviours at a more profound level (Figure 5).

5.1 The "Stimuli" in the "Dark Mode"

The introduction of "dark mode" was in response to

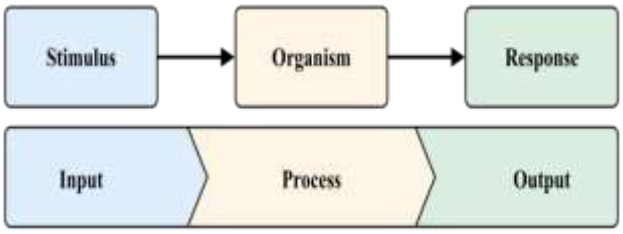

Figure 5. *S-O-R theoretical framework*

providing an opportunity to have a change in colors that would present a different experience [6]. Previous studies suggest that "dark mode" causes perceptual, cognitive, and physiological responses in users' under specific conditions, factors, and features. As stated in this paper, there are four stimuli per several research topics. The first two as mentioned are 'external factors' affecting the working of the games which are beyond the control of the developers or the designers involved in the project. The last two categories specified as 'internal' factors are the variables that can be changed internally by the tech developers or the persons responsible for the product management and design [37,52]. The first is the ambient lighting of the "dark mode", which is mentioned in several articles as a factor that can potentially influence users. The second category includes primary users or sample subjects of the "dark mode" under investigation, for which distinctions should be made regarding age, physical condition, as well as a professional degree [19,49]. The third category is the ones that can impact and modify the user experience. For instance, the visualization characteristics of the VR devices are not the same as the computer displays [5,57]. The fourth type of intra-ad elements is 'content', which encompasses texts [35], colours [38], graphics [53], images [57], and luminance/contrast [50]. These particular studies indicate that the 'content' factor also plays an important role in evoking the cognitive, perceptual and physiological responses of the end-users of "dark mode" (Table 7).

5.2 The "Organism" in "Dark Mode"

Perception, physiology and cognition as they pertain to users' experiences in "dark mode" are referred to as "organisms" in this study. In contrast to perception, which is an emotional and mental state brought about by direct sensory input, cognition is an action that impacts subsequent thinking, comprehension, and acquisition of knowledge by inverse, inferred, and non-sensory means. The difference between a physiological response, which impacts the body and its internal organs, and a psychological displayed perception is that the latter is an evaluation reaction [69]. Results from the above research suggest that the "dark mode" primarily influences the visual senses via the 'visual,' leading to a perceptual and physiologic responses in the user and, ultimately, a cognitive response. As mentioned in Table 8, the primary perceptual response concerning the "dark mode" includes 'Attractive', 'Personalized', 'Fun', etc out of which 'Fun', 'Security Feeling', 'Visual Appeal' are positive affective states, and 'Depression' and 'Loss' are negative. This means that the same design pattern can cause different levels of perceptual response in case of different usage contexts with different devices. For example, "dark mode" has attributes that foster moral integrity, in addition to offering an element of safety [20]. The variability in backgrounds also brings an element of pleasure. Apart from that, the experience of being in darkness is the feeling of the loss of connection with reality, and the choices are more real when users choose hedonism rather than utilitarianism.

Furthermore, the "dark mode" enhances enjoyment because it personalizes the choices. However, this colour mode can cause a depressing feeling,

Table 7. *Summary of stimuli in the "dark mode"*

Stimulus	Classification	Reference
Ambient lighting	Dusky	[1], [3], [7], [8], [13], [19], [20], [22], [24], [36]-[38], [41], [46]-[50], [52]-[55]
	Bright	
Sample variation	Test subject • Involving human subjects • No human subject involved	[7], [13], [22], [40], [42]-[44], [47], [51], [52], [55], [57]
	Age • Young • Middle Age • Elderly	
	Health conditions • Normal vision • Eye disease	
	Level of expertise • Expert Team • General Users	
Equipment	Computer	[1], [5], [7], [9], [13], [20], [22], [35]-[37], [46], [48], [52], [53], [56]
	Mobile phones	[14], [42]
	Immersive equipment • VR • AR	[3], [19], [47], [50], [57]
	Display screens • OLED • LCD • CRT • TFT-LCD	[23], [24], [38], [39], [41], [51]
	E-reader • E-Ink • Electronic paper	[40], [45], [49], [54]
Content	Text • Style • Size • Thickness • Line spacing	[7], [8], [13], [37]-[39], [40], [43], [46], [47], [51], [55], [56]
	Colour • Saturation • Colourways	[1], [3], [9], [23], [38], [39], [68]
	Images • Clarity	[19], [50], [53], [57]
	Graphics • Shape	[13], [22], [39]-[41], [53]
	Contrast ratio • Low contrast ratio • Medium contrast ratio • High contrast ratio	[1], [3], [9], [22], [23], [33], [37], [39], [41], [43], [45], [47], [52], [55]-[57]

especially in situations like chat or in cases where the colour in the interface is sparse [13]. Curiously enough, due to prolonged experience in using light mode, patients experience aesthetic fatigue and, potentially, the psychological effect of blue color impact; as such, they begin to despise light mode and deem its interface subpar [5], [70]. Changing to "dark mode" may sometimes give a feeling of pride in the user interface [13], [68].Table 9 provides information on physiological states that have been analyzed in the "dark mode" studies. The most common physiological responses observed in the available studies were predominantly ocular changes. Therefore, the beneficial low light in the "dark mode" reduces the excessive exposure to the screen lights, including the detrimental blue light. By reducing the level of blue light, its impact on melatonin inhibition can be minimized in the "dark mode", which will help improve the quality of sleep of users who are used to relying on their mobile devices before going to bed [42]. In low lighting conditions, there is reduced visual load and thus the elderly are less fatigued when using a "dark mode"

Table 8. *Summary of perceptual reactions in "dark mode"*

Perceptual Reactions	Description and Definitions	Reference
Attractive	Contrasting colours and items used in the "dark mode" can make social media attractive and fun, whereas its use can lead to improved interaction.	[5], [71]
Personalised	The black-and-white color contrast of the "dark mode" is different from the widespread black letters on white background. The singularity has potential to provide people with an opportunity to express themselves and receive attention.	[5]
Fun	Perhaps pleasure might stem from the transition of the background colors from light to dark. The element of secrecy of "dark mode" has an impact on the decision of the user to choose hedonism over utilitarianism and enhance the level of enjoyment.	[5], [19], [50], [70]
Negative emotions	Colour can capture both the hedonic tone and the activation level of the emotional experience. Even in normal ambient light, the mood in "dark mode" reduces the user's ability to perceive emotions and causes a depressing nature.	[13], [53], [68]
Visual acuity	During the night-time or in dimly lit areas and when the background is rich and complicated, it seems easier to recognize characters or visual properties in the "dark mode".	[3], [9], [19], [72]
Visual Aesthetics	In terms of overall image quality, a uniform background ensures that light crisp and clear while bright text on a dark background provide an aesthetically delightful appearance.	[9], [13], [23]
Sense of security	"dark mode" enhances user realism. In the long-run experiments, users are likely to be more honest when in the "dark mode", it also encourages ethical behaviour for the best results.	[20]
Pride	It is because of the trade-off between light and "dark mode" People have fatigued in aesthetic and exposed to excessive blue light In addition, they have contempt for the light mode but take pride in the "dark mode".	[13]

Table 9. *Summary of physiological reactions in "dark mode"*

Physiological Reactions	Description and Definitions	Reference
Visual comfort	Consequently, higher usage of the electronic devices in the long run preferred the "dark mode"s, providing lower light stimuli to the eyes hence increasing the work and reading time.	[3], [5], [19], [50]
Fatigue reduction	Research shows that "dark mode" has a positive impact on the perceived level of visual fatigue. This means that the application of higher blink rates, as well as papillary accommodation, is able to minimize the sight-related fatigue that comes from electronic device usage at night when in "dark mode".	[1], [19], [33], [23], [51]
Improve vision	When evaluating the results of the ANOVA it was observed that the polarity factor was the only factor that was statistically significant in regards to the assessment of visual acuity. The elderly and the youths complained of reduced vision when using the lighter version of the mode, but the results proved that the mode's dark variant provided sharper vision as compared to the brighter one.	[33], [51]
Promote sleep	The interference with sleep that accompanies the use of gadgets in the late evenings and the impact that light has on melatonin release may be mitigated with the help of the fresh "dark mode" feature.	[42], [57]
Cybersickness	Scientists proved that some of the users may develop motion sickness that is associated with salivation when using VR devices in the "dark mode" for long.	[57]
"Glare and reflection problems"	"Dark mode" may result in glare and reflection, since lobes dimensions and form were significantly impaired under negative polarity scenarios.	[37], [56]

Physiological Reactions	Description and Definitions	Reference
Blurred vision	Low luminance of the "dark mode" causes pupil dilation and the field depth decreases and spherical aberration becomes bigger and retinal imaging becomes blurred which leads to blurred vision.	[7], [37], [56]

Table 10. *Summary of cognitive reactions in "dark mode"*

Cognitive Reactions	Description and Definitions	Reference
Legibility	In the darkness, the "dark mode" reveals improved reading times and high readability compared to the light mode, especially for users with diminished vision (e.g., elderly/cataract patients). "dark mode" is more readable when it comes to fine characters and is suitable to be operated in dark backgrounds.	[19], [23], [40], [45], [46], [48], [50], [74]
Inhibiting legibility	One may argue that visual acuity is reduced in "dark mode" because, as the pupil dilates on the incomplete surface of the eye, sensory aberrations are introduced and conflict with the visual cognitive process. On the other hand, lighter mode displays are preferable when the ambient light levels are high for better readability.	[35], [37]-[39], [46], [49]
Usability	Overall, there was a perceived increase in ease of use (less lag, more enjoyable) in relation to the AR text annotations in "dark mode". A substantial primary impact of darkness mode on total availability depends on accessibility quality, which incorporates both the utilitarian and hedonic aspects of the low-light setting and "dark mode."	[19], [50], [62]

[3], [51]. Apart from nighttime, the "dark mode" is beneficial to anyone who uses devices such as computers and phones for work or reading for prolonged periods. On the other hand, some virtual reality headsets have poor ambient light management, which means that users may spend longer time in a dark environment and experience vertigo as a consequence of physical stress. On top of that, DM may make your eyes water [56] and make your vision blurry [7], [57] since it has a low illumination level and makes the eyes narrow.The cognitive responses to "dark mode" are summarised here, based on Table 10. It follows that a number of studies have linked these substantial cognitive responses to comprehension and reading abilities affected by legibility, i.e., the readability of the typefaces or texts used across different media. According to Poole and Ball (2006), there are two main variables that affect a text's readability [73]: the first is the text's degree of complexity, and the second is the text's exposure and the viewer's ability to immediately recognise it. Thus, the amount of time it takes to read under the identical testing settings reveals how easily the user can extract and understand the information. Dobres et al. (2016), found that when reading the same material takes more time, the readability drops and users are unable to absorb and comprehend the information. The "dark mode" is more detrimental to reading than the "light mode" according to some investigators; this is because, due to the pupil dilation effect, it has lighting and identification issues that make visual perception problems worse and distract the reader [45]. The "dark mode" provides the user with noticeable benefits while interacting with the interactive interface, leading to an overall greater usability quality in terms of effectiveness of use, comprehension, and ease of operation.

5.3 The "Response" in "Dark Mode"

Within the context of this study, 'response' has to do with the result of employing the "dark mode" and assists in shaping the response of the user as to whether they should continue to employ the "dark mode" or not. When it came to the user responses to the "dark mode", comprehensibility, task effectiveness, physical discomfort, and intention to use were some of the response variables mentioned; The positive responses to the "dark mode" are presented in Table 10, while the negative responses are presented in Table 11. In regards to the comprehensibility, as seen earlier in this paper, the length of the text is directly proportional to the readability ease or comprehension level. In the negative responses, many have complained that text reading in "dark mode" is slow, illegible, and hampers comprehension [13]. Specifically, in the case of LCD screen devices, the "dark mode" presents poor readability and makes the reading process and the overall comprehension much harder. Higher cognitive load also means that using negative polarity results in longer search time and larger pupils among the elderly in a bright context. On the positive side, respondents acknowledged that "dark mode" during low light settings enhanced focus and

ease of reading [5]. Those who favored the "dark mode" were considered to be more experienced in the use of computers for a longer period, with enhanced reading and comprehension in the "dark mode" only. Further, concerning image quality, the "dark mode" is preferred since it consistently achieves the best lettering that supports reading and understanding text on the CRT displays [48].

The issues such as precision and clarity of vision as well as the ease of understanding of the layout of the interface will play a key role in the ability to perform the search and proofreading tasks correctly during the task. Some authors have indicated that the "dark mode" is better under low light environments in terms of proofreading time and error rate on the task [19]. Other scholars have opined that lighter patterns indicate higher brightness; and with a certain degree of brightness, more or larger pupil contractions; which in turn gives a better projection of patterns on the retina membrane that has better definitions of images and perceived perception thereby giving better or improved collation. As a result, compared to the light mode, "dark mode" exhibits more acute image quality, sensitivity, and task productivity due to increased retinal image blurring caused by decreased luminance, recognition, and editing performance, particularly in contrast scenarios in which color elements impact the ocular pathway's contrast mechanisms [36].

Once again, we observe that good responses are more prevalent than negative ones from the bodily symptoms. Those who suffer from eye problems or spend a lot of time staring at screens may benefit from dark patterns, since they have been shown to improve eyesight and sleep quality [7], [37], [56]. Contrarily, research has shown that using "dark mode" while working might lead to back discomfort and muscular tension [22]. Similarly, the dark backdrop causes the pupils to dilate, which in turn causes impaired vision and glare [40], [55] Furthermore, users of head-mounted displays (HMD) like virtual reality headsets may feel some anxiety from being in the device when it's in "dark mode" without properly adjusting the brightness level [57].

Finally, with regards to the 'intention to use', it has been said that ambient illumination has a large major influence on overall preference, according to affirmative replies. Because of its energy-saving features and its impact on "readability, perceptual quality and visual comfort" in low-light environments, "dark mode" is likely to be the preferred viewing mode for most users [3], [5], [50]. Researchers generally agree that darker patterns are more appealing to consumers. In contrast, many academics believe that reading against a white backdrop is more like reading a book, given the long-established reading habit of black text on white paper and the fact that white is more reflective of the actual environment. Gestalt psychology suggests that using a black backdrop with white lettering is more similar to reverse contrast. As a consequence of adjusting to a new color scheme and reading style, users undergo a process known as an adaptation when the backdrop colors are changed [35], [45]. Because of this, "dark mode" may be disregarded (Table 12).

6. UX Research Framework for "Dark Mode"

This is obvious from the literature review portion of the study where the authors highlight that while there are minimal studies on the extent of dark patterns in the past, comparable polarity approaches have been explored far earlier. The current available research evidence reveals high levels of contradicting opinions towards using "dark mode" theme and majority of the related studies are inconclusive in focus, unidimensional and lack systematic consideration and comprehensive research framework to examine the research relationships between these variables and the rationale for such differences. This article presents a versatile and comprehensive research framework for studying dark patterns, based on the S-O-R as shown in Figure 6. In the "dark mode", the user's perception, intellectual, and physiological features are impacted by the external environment, the study's object, and the subject device's internal and exterior elements, as shown by the literature review analysis. Learning about the "dark mode" has sparked a lot of debate and new ideas in the field of study. So, according to the research framework presented in this paper, it is feasible to understand the user's experience with dark patterns and the way they lead them to the desired behavior, as well as the differences and significance of the stimuli elicited by these patterns in terms of their impressions and cognitive responses. In order to go beyond simply affirming or rejecting the system of the "dark mode" based on one aspect of the research findings, it is important to thoroughly examine and analyze the subject, their device, the external setting, and internal elements while researching and developing the "dark mode." This will help identify its strengths, weaknesses, and potential for improvement. Nothing is known about the relationship between "dark mode" and user behavior or experience from previous research. However, there are a lot of publications showing that the "dark mode" system's internal and exterior cues promoted various user behaviors via the positive mediation of their perceptual, cognitive, and physiologic reactions. Consequently, according to

Table 11. *Summary of response in "dark mode" (positive outcomes)*

Positive Response	Description and Definitions	Reference
Highly comprehensible	People who used a "dark mode" in low light conditions reported elevated levels of concentration and comprehension of what was being read. Lovers of the dark theme recorded better results in all other manifestations; the drawing of the text was faster on dark backgrounds as well as better for reading.	[3], [19], [9], [39], [5]
Smooth task performance	The experiments using the control and the experimental websites showed that in the low light conditions, the "dark mode" increased the total number of completed tasks, and decreased the cumulative errors and the time taken to complete the tests.	[19], [41], [57]
Reducing disease symptoms	The "dark mode" is useful in lessening the visual burden, particularly in night-time shooting where using "dark mode" minimizes harm from electronic devices to people's eyes and enhances vision, advances circadian rhythm during the night, and facilitates sleep.	[1], [19], [23], [42], [50], [51], [57]
Preference for use	After sunset, test subjects lean towards darker colours. Besides the performance consideration asserting that "dark mode" prolongs the endurance of the device and the time it is in use, the aesthetic presentation of the "dark mode" as well as being easily personalized add to the reason why individuals choose it.	[3], [19], [44], [50]

Table 12. *Summary of response in "dark mode" (negative outcomes)*

Negative Response	Description and Definitions	Reference
Cognitive burden	The font form and text information in "dark mode" are less distinguishable from the background compared to that in the light mode. Thus, the "dark mode" text, in general, takes more time for the reader, has decreased readability, and reduces comprehension. In the case of elder people there is more effort in their mental processes when having to perform the negative polarity search task in a bright environment.	[13], [22], [37], [46], [48], [49]
Obstructed task performance	It is proved that brightness does play a major role in length of search activity and as the brightness increases the time taken also decreases. Higher light intensity and the lighter shades of colours increase the degree of precision while lower light and night modes affect the functionality of the task control and the degree of precision in the performance of the task at hand.	[35], [38]; [36], [40], [49], [54], [57]
Physical discomfort	Young users experience muscle strain and back pain when studying in both dark and light modes, while elder users had the same problems after using the "dark mode" with the addition of dizziness when using the head-mounted VR device for an extended period. Furthermore, the research revealed that dark colour mode could cause glare and fuzzy vision where the priority is given to performance above vibrant colours.	[7]; [22], [37], [56], [57]
Prefer not to use	Concerning mode preference, subjects displayed more preference for lighter mode and subjectively denied the darker mode. This may be related to their usage habits, where users are exposed to white and black text every day and they do not utilize dark background formats.	[1], [35], [36], [45]

this model, the user's intended behavior is triggered by the perceptual, cognitive, and physiological reactions (organisms) that occur as a result of the user's involvement with the dark pattern (stimuli).

7. Discussion

While the commercial field has paid due attention to the "dark mode" l, the academic field has paid limited attention to the "dark mode" l, and no work systematically reviews and discusses the knowledge that exists on the "dark mode"l, its notions, its design systems and the user experience procedures. Therefore, referring to the "dark mode" as a screen display technology, this paper synthesizes and analyzes literature data from the last twenty years, uses the qualities of dark or black background with light or white fonts (negative polarity display) of this technology as the basis for expanding the range of the researched variables and integrating them into the analysis in terms of the systematization of the framework for the study of "dark mode". In this way, it can serve as a paper for the study of "dark mode", and researchers can refer to this theoretical framework to comprehend, verify, and extend the study of "dark mode" in the future.

7.1 Theoretical Implications

First, this paper provides the state of the art of the

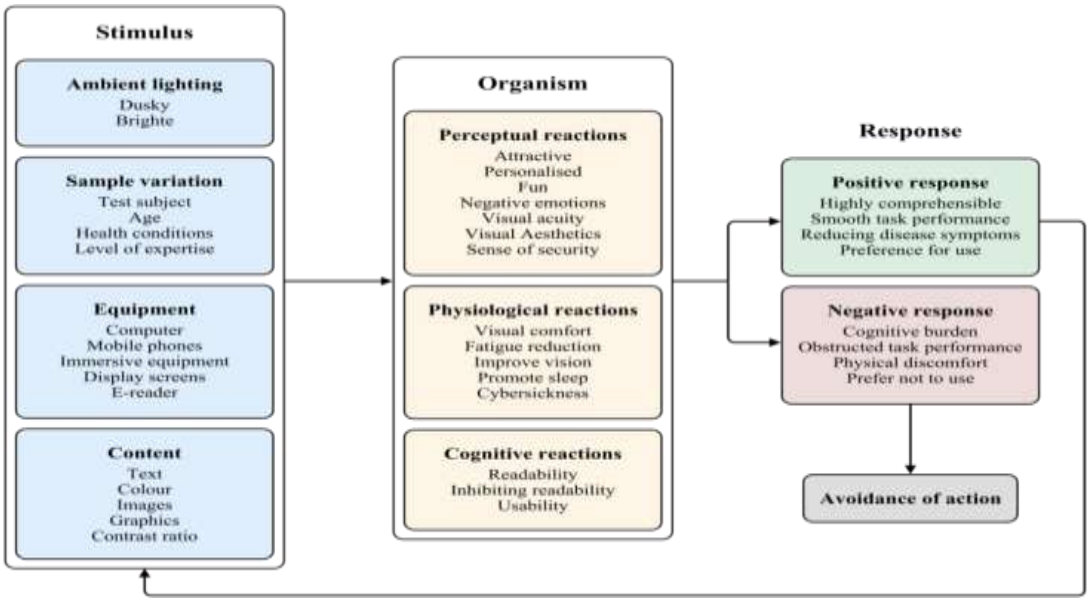

Figure 6. *UX research framework for "dark mode"*

"dark mode" as follows: It discloses the bibliographic information about dark patterns, the research background, the research methods, the pertinent theories, and the research trends, thereby offering several significant contributions to the academic discipline. First of all, there were no studies on the academic level exploring the "dark mode" with reference to the advancements in the commercial sphere of activity, and there are no studies that present a systematic analysis of the literature. There are still many researchers who do not know much about the "dark mode", and it is quite difficult to find a research direction. However, the general technique of using a negative polarity, such as the "dark mode", is a concept that has been researched and covered long before "dark mode" became a phenomenon. However, it is used in its more recent commercial form where it is not directly available in academic literature. It is not only the latest technical research paper in the "dark mode", but also supplemented with the negative polarity technique research data and analysis to be slightly stronger in line with the nature and characteristics of the "dark mode", and the closely related positive polarity technology is the light color mode. It can assist the researcher in understanding the state of "dark mode" in terms of the topics discussed, background, disciplines, theoretical background, utilized research methods and future trends. Secondly, for this paper, the factors related to "dark mode" are incorporated into a multi-faceted research approach regarding the user experience of "dark mode". Therefore, it can serve as a useful reference for subsequent scholars in constructing new research theoretical models for the understanding of "dark mode" user experience, the system design of "dark mode", as well as the relationships between "dark mode" and user experience. Therefore, this paper, by briefly summarizing the literature, informs the sources of the mentioned controversial issues and gaps in the research, as well as the research variables and factors obtained through the literature review that can help future research from various angles.

7.2 Practical Implications

Researchers and equipment makers working on "dark mode" system development will find this study valuable. This paper's overarching goal is to lay out a detailed framework for the "dark mode" user experience, one that takes into account the "dark mode" systems (both internal and external factors), the user's perceptions and thoughts, and finally, the user's actions. This framework should shed light on the complex web of relationships between the "dark mode" and the user's surroundings, as well as their own physiology, perceptions, cognition, and behaviour. Furthermore, it is also found that user experience in "dark mode" has its positive and negative sides, thus the system developer or designer who is involved in the "dark mode" can take the light of the "dark mode" experience framework and related factors mentioned in this study, to weigh the pros and cons of the dark and plus try to work at maximizing the benefits of "dark mode" while minimizing the negative sentiments that people have towards "dark mode".

7.3 Future Research Agenda

Methods for researching the user experience of "dark mode" should be diversified

A literature review analysis reveals that, in "dark mode" studies, experiments and questionnaires are

the most commonly employed techniques. While employing a quantitative approach can give direct empirical evidence, the variation in findings across quite a number of papers is markedly high such to the point that two papers may offer diametrically opposed perspectives towards a specific aspect of a study. Cited authors have failed to highlight the rationale behind the results of the user study which is a natural drawback of the findings made. Finally, those works that have employed only a single type of experimentation may also influence the results of the study, given the practical constraints of its operation and the reliability of the collected data. Hence, it is recommended that future research should adopt mixed research methods in order to increase the type of research method for richer research information and findings. It is also important to reassemble objective evidence to confirm the findings of the research or check its accuracy, including the collection of subjective data as artefacts to prove the reliability of the research result and obtain sufficient explanations. For instance, in the study by Pedersen (2020), he connected the experiment with the interviews and showed that while some users did have negative responses to the "dark mode" in the experiment, during the interviews, it was revealed that they preferred using "dark mode" [5]. Subjectively, these users care mostly about the looks and feel of the "dark mode" as for the speed and errors that occurred while completing the tasks in the "dark mode". This accounts for why the experimental data does not align with the preference findings.

Incorporating more specific theoretical frameworks for research

Especially in the literature reviews related to the "dark mode" above, it can be noted that the vast majority of them have not been derived from the systematic analysis of the theoretical framework but appear to look for possibilities in the samples, devices or stimuli. Therefore, the findings are not comprehensive of the experience that users go through. Furthermore, the majority of the presented work describes an objective research outcome that does not explain the theoretical background and rationale for these results, despite them being general and not very profound and nuanced.

Expanding the type of sample and enriching the context of the research subject

According to the bibliometric analysis, most of the studies have employed 'students' as their subjects for data collection. However, the participants in the study are only the students which limits the population and experience while the "dark mode" is well-known among various segments of the population and it is possible that sample restricts the generality and relevance of conclusions. Hence, the future development of such studies should embrace adorned user samples and take into account various users' backgrounds to avoid the noted shortcomings.

Understanding the negative consequences of the "dark mode" user experience and solutions for improvement

To summarize the discussion from the literature review, it is evident that "dark mode" has a significant capacity to optimize the user experience. But, this is not the only benefit of using "dark mode", as it has its downsides as well. Many of the studies grew out of a conversation about the benefits of using "dark mode" and do not have a critical perspective on the negative impacts of this method. Other research indicates negative reactions to dark patterns since people get fooled; however, further solutions have not been considered. The consequences associated with the "dark mode" should in the future be enhanced by the integration of technology, the actual user experience and self-assessed needs of the users. For instance, gathering information on individual traits and the recommendations provided by various users might be a possible approach to addressing the harms brought by dark patterns.

8. Conclusion

"Dark mode" becomes more popular in everyday use as display technology advances and users' demand evolves dramatically. Therefore, there are gaps that require further research and discussion on "dark mode". In the future, more empirical research should be carried out to verify the "dark mode" UX framework introduced in this paper, establish a more systematic and comprehensive research framework for the existing research limitations, and provide possible solutions to the problems in the user experience of "dark mode". This paper lays the groundwork for the subsequent researchers to grasp the historical background, present state, and focus of the "dark mode", while also offering a clear research roadmap for further investigation.

As a result of the time frame and the range in the collection of database fixed in this study, the research in this paper can only detail the empirical research of "dark mode" in the Scopus database of the last three decades, while other empirical research beyond the last three decades has not been explored and detailed yet. Furthermore, the search terms used in this paper are limited to those presented in the table in the text, and it is for this reason that the research has not delved into and analyzed search results beyond the specified range in this paper. In the future, with more and new knowledge about "dark mode" technology and its use, there may be

new situations which the later research may discover next.

Author Statements:

- **Ethical approval:** The conducted research is not related to either human or animal use.
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