

Eye Tracking and Visual Attention to Live Streaming

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The COVID-19 pandemic has led to the development of a new business model, “Live Streaming + Ecommerce”, which is a new method for commercial sales that shares the goal of sustainable economic growth (SDG 8). As information technology finds its way into the digital lives of internet users, the real-time and interactive nature of live streaming has overturned the traditional entertainment experience of audio and video content, moving towards a more nuanced division of labor with multiple applications. Researchers have used eye tracking technology in order to understand consumers’ visual search methods and decision-making processes.

Keywords: eye tracking ; ecommerce live broadcast ; visual attention

1. Introduction

The United Nations launched 17 Sustainable Development Goals (SDGs) in 2015, including 169 targets that can be grouped into three pillars of sustainable development: economy, society, and the environment [1][2]. Interdisciplinary cooperation with other parties is required to achieve the SDGs, as the goals relate to all aspects of human endeavors, and in this context, business operations play an important role in supporting the achievement of the goals, as they involve many business activities that contribute to the improvement of living standards [3][4][5][6].

The impacts of the COVID-19 pandemic on governments, industries, and all business activities worldwide have seriously challenged the achievement of the SDGs and increased the complexity of the intersecting SDGs [7][8]. Due to this impact, the need for digital technology applications has increased, and the study published in The World in 2050 (TWI205), Transformations to Achieve the Sustainable Development Goals, recommends that the world adopt the United Nations SDGs as the basis for immediate key transformations [9]. Under the influence of COVID-19, many brick-and-mortar shops and businesses closed down; however, online businesses benefited from the growth of the “Stay-at-Home Economy” [10][11][12]. As a result, existing online business models flourished around the world during the pandemic, giving rise to a new business model: live ecommerce platforms, which share the goal of sustainable economic growth with SDG 8. This reinforces the fact that during the pandemic, going out has been reduced but not spending, and online and offline commerce can play complementary roles [13][14][15].

The main consumption scenario of consumers has changed from brick-and-mortar shops to business activities in an electronic form combining the internet and commerce (ecommerce), meaning the T2O (TV to online) business model, which links television programs with ecommerce to create an innovative model of combining live streaming with ecommerce. This business model has brought a new shopping experience to consumers and created the so-called “internet celebrity economy”, which has created opportunities for the development of live ecommerce [16]. Live ecommerce is a new business model driven by real-time interactions, which effectively stimulates consumers and develops consumers into fans to follow the live broadcast through entertaining live content that meets their needs [17][18][19], thus bringing money-catching (eye-catching) traffic to the live shows and, in turn, providing a new channel of interaction and communication between consumers and merchants [20]. Consequently, ecommerce platforms have been actively joining live ecommerce in recent years [21]; for example, Taobao, JD.com, Jumei Youpin, and Facebook fan pages have all launched live ecommerce features [22][23].

According to MIC’s survey data on live streaming in Taiwan, 31.3% of Taiwanese netizens follow a specific live streamer (a user who plays the role of a live stream host), and 78.4% of those who watch video and audios online have watched a live broadcast [24]. However, live streaming is not just a one-sided personal showcase for the live streamer, it also includes the interactions and reactions of the live viewers to the content of the live stream, which together form part of the live ecommerce platform. Thus, how to make consumers willing to learn about brands and products, share their ideas and needs, and receive immediate responses from live streamers have become the most important issues for live ecommerce to create a new commerce model different from the traditionally static way of displaying ecommerce products [25]. Most existing study methods of ecommerce live streaming are based on questionnaires or interviews, which are used to infer

the participants' mental activities. However, these study methods may be biased by the participants' memory errors, introspective correctness errors, or subconscious attempts to conform to social expectations, which may result in the research data not being detailed enough or not being able to observe the overall cognitive process, causing invalid data and experimental bias [26].

Due to the ease of use and maturity of eye tracking technology [27][28], eye tracking research has been used in a wide range of research fields since its inception for reading behavior analyses, such as cognitive science, psychology, human factors engineering, human–computer interaction interfaces, virtual reality, digital learning, artificial intelligence, machine learning and so on [29][30][31]. Eye tracking technology uses the principle of image processing to capture the infrared rays reflected from the pupil and records eye movements using a special camera that locks onto the eyes to analyze the eye tracking process. The observation and analysis of eye movements also facilitate the study of users' perceptual recognition or attention distribution, thus, inferring their cognitive processes [32][33]. Fixation and Saccade are two of the most commonly used methods to process data in eye tracking studies [34][35][36]. "Fixation" is defined as the state of visual attention to a specific area between one eye movement and the next, and is the primary means of receiving visual information. "Saccade" is defined as a continuous and rapid movement between eye fixation points, meaning a rapid eye movement that leads to a specific visual target [37][38][39]. The sequence of eye movements, which includes saccade and fixation, is known as the scan path. In addition, in the process of studying eye tracking technology, in order to record and analyze the eye movements of users' browsing behavior in a physiologically and psychologically unaffected state, researchers must set regions of interest (ROIs) to observe and collect eye fixation and visual behavior at certain locations [40][41][42][43][44]. Based on the interactions of the ROIs and visual information, the latency of first fixation (LFF), duration of first fixation (DFF), total fixation durations (TFD), and number of fixations (NOF) are commonly used as evaluation criteria for processing eye movement data [45][46]. In recent years, the rapid development of the internet has led to the explosive growth of ecommerce, resulting in innovative models for live ecommerce. By recognizing the importance of the behavioral process, some researchers have used eye trackers to record the order in which consumers browse products, as well as the length of time they spend on messages in a particular browsing task or behavior, in order to understand their visual search methods and decision-making processes.

2. Business Model and Studies of Live Ecommerce

With the popularity of mobile vehicles, the rapid development of 5G, and the rise of the OTT (over-the-top) audio and video industry, live streaming applications have formed a whirlwind, and the in-depth combination of online live streaming and ecommerce has attracted a large amount of traffic and business opportunities for live ecommerce [47]. In view of this, many ecommerce companies are hoping to use the appeal, performance, and influence of internet celebrities to promote their products, thus, creating the so-called internet celebrity economy and increasing the likelihood of potential consumers [48]. The first year of the "live streaming + ecommerce" model was 2016, in which internet celebrities used their image, appeal, or influence to deepen consumers' impressions of their products and brands, thus, turning their popularity into online profits, which creates a win–win economic model for ecommerce, sellers, and internet celebrities [49]. In recent years, many scholars have used questionnaires or interviews to explore how live ecommerce, meaning the new form of online media with interactive and real-time characteristics, increases consumers' urges to buy and consume, as well as their desire to experience and be entertained, based on the premise that live ecommerce can attract consumers' attention and satisfy their shopping needs through the TV to Online mode and TV Shopping [49][50]. Such studies are both effective and instructive; for example, one study showed that three types of motivations, namely "information motivation", "social interaction motivation", and "entertainment motivation", have a positive impact on the frequency of use of live ecommerce. Moreover, the extroversion and openness of the users have a positive predictive effect on the motivation for, behavior in, and satisfaction level with live ecommerce. Using a structural equation model, a post-acceptance and continuous adoption model of information systems was used to explore user behavior on Twitch, which is a live webcasting platform, and the results showed a significant effect of cognitive interactivity on perceived usefulness, a significant effect of perceived usefulness on satisfaction and intention to continue using, and a significant effect of satisfaction on intention to continue using. Previous studies have indicated that highly motivated community participants are more likely to generate brand trust, which in turn increases the psychological attachment of fans to brands and leads to their long lasting relationship with the fan page [5]. It was also found that a live presence had a significant positive effect on online interactivity and message credibility, online interactivity and message credibility had a significant positive effect on identity, and identity and affordability had a significant positive effect on consumers' purchase intention, where affordability mediated the effect of identity and purchase intention. A social motivation model with eight factors was constructed based on the use and satisfaction model to explore the level of engagement of four-sided live viewers, and the findings showed that less-viewed live platforms had a higher social engagement motivation than more-viewed live platforms [51][52].

3. Eye Tracking Technology and Related Studies

For most human beings, 80% of information processing relies on vision; thus, studying eye movements is considered to be the most effective tool in visual information processing and the most important source of sensory information in cognitive processing [36]. The main reason is that eye movements can be effectively used to capture the complex cognitive processes of human visual information, meaning they can be used as a technique to locate where people are looking [53][54][55]. Unlike previous cognitive processes for individuals, eye movements can also effectively characterize the information processed during the reading process and provide external behavioral indicators [56][57][58]. Therefore, eye tracking is considered to be a measurement technique that reflects the visual information process, helps researchers to record the fixation positions of the participants' eyes at a given time, and displays the movement sequence and trajectories of the information. Eye tracking technology provides an important tool for the natural and online exploration of cognitive thinking, which reflects the correlation between eye movements and psychological changes in readers when receiving information [37]. This technique has been widely applied to understand the reading process, as well as other related topics and research experiments, such as eye movement characteristics, perceptual span, and information integration. Eye movement data are also used to examine the cognitive processes of different cognitive tasks, and in many studies related to eye tracking, total fixation durations, the number of fixations, and the sequence of fixations are the most frequently investigated variables [56][57]. When the eye is in fixation or saccade, it indicates visual attention. Eye movement processes, such as fixation duration, fixation position, and visual trajectory, can be used as bases for assessing whether visual behavior is being attended to [59]; for example, researchers have shown that the fixation durations and the number of fixations are directly related to preference, where shorter fixation durations or fewer fixations indicate a lower preference, while longer fixation durations or more frequent fixations indicate a higher preference [32][60]. An experiment was conducted with 33 participants using an eye-monitoring device to investigate the relationship between eye tracking and landscape preference, attention, image characteristics, and the number of fixations, and the results showed that the total number of fixations was influenced by preference, and that preference factors varied with personal factors, such as professional background or sex [32][34][61].

4. Eye Tracking Technology and Visual Attention

Recent advances in computer processing technology have led psychologists to believe that the human psychological function is similar to that of computers [62][63], i.e., the structure and process of human psychological functioning can be understood through the way that computers process information [64][65]. At the same time, the relationship between the perceptual information processing theory and cognitive processes has led many researchers to conclude that eye tracking technology is the most direct and effective way to study visual information processing, observe the reading patterns and visual attention of different learners, and even as a tool for teachers to diagnose learning disabilities [66]. The eye movements commonly observed and recorded in eye tracking are Fixation and Saccade. The Scan path refers to a series of fixation points and sweeps, which are the conscious eye movements associated with attention shifting, higher-level memory, and comprehension of cognitive processes.

Another study investigated the relationship between students' reading comprehension and visual attention when reading Chinese sentences with misplaced words by combining eye tracking technology and an electroencephalogram, and the results showed that misplaced words did not affect reading comprehension and that increasing the number of misplaced words in a sentence did not affect the fixation duration. An empirical analysis that used eye tracking technology was conducted to investigate how graphic design in e-books with a high and low correlation affected learners' visual behavior and learning outcomes when learning single Spanish words [67][68][69][70][71]. Eye tracking technology was used to investigate the differences in the order of seeing and reading, as well as the cognitive span of native Japanese learners, when they viewed words in their first language (L1) and second language (L2). The empirical results of the study showed that for L2 readers, reading was more important than seeing, and there was a difference in parafoveal processing between L1 readers and L2 readers when reading target words in sentences [72][73]. In addition, in order to understand the effectiveness and concentration of learners in game-based learning, a study on the design and development of digital games using eye tracking technology found that visual trajectories were used to analyze learners' learning processes, and that incorporating game features with rules and objectives in the games was effective in capturing learners' attention [74][75][76].

Visual behavior, processes, and achievements in game-based learning (GBL) have been used to explore the differences between players with medium-high and low conceptual comprehension in visual behavior and game process in GBL using eye tracking technology [77]. The results suggested that players in the high comprehension group showed effective text reading strategies and better metacognitive control of visual attention during gameplay. Another study explored the impact of using a simulation environment with animated agents on the visual attention, emotion, performance, and

perception, in order to assess how animated agents of emotion in simulation-based training affected the performance outcomes and perceptions of individuals interacting with the training application in real-time. The results of the study showed that both experienced and novice participants focused more visual attention on the animated agents than on other defined regions of interest in the simulation environment [78]. While multiple choice (MC) based on visual attention is an important form of testing to assess students' academic performance in eLearning, MC question evaluation indices (e.g., correctness rate) only consider the correctness of the final choice but ignore the process that led the participants to select the answer. The experimental results showed that including this measure could reflect differences in fixation movements and help teachers infer the true academic level of students [79].

Eye tracking has been used to study students' visual attention to solve upper-level physics questions, and to identify the differences in understanding and cognitive processing when solving questions in a graphical and abstract mathematical manner. The fixation patterns and associated eye-tracking measures suggested that the two visual strategies had different cognitive processes, and the different strategies led to different fixation patterns and learning outcomes [80]. A comparative analysis of Facebook online advertising attention using eye tracking technology was conducted to explore the eye tracking indices and Facebook advertising attention behavior [81]. VR eye tracking was used to explore how prior knowledge affected the visual attention and learning outcomes for Japanese mimicry and onomatopoeia, and the results of the study showed that learning in VR improved attention to learning [82][83][84][85]. A study investigating the educational effects of anthropology through a GBL approach was carried out to learn about the association between game immersion and visual attention distribution. The eye tracking technology showed that students who played anthropology in an immersive manner were more focused on the played character [86]. In a study of viewers' visual attention to subtitles in home shopping broadcasts, eye tracking technology was used to obtain objective data on visual attention to home shopping subtitles and to determine the factors that draw the visual attention to subtitles on television home shopping screens. In addition, an eye tracking device was used to propose an effective method of producing and directing home shopping subtitles [87].

References

1. Gunawan, J.; Permatasari, P.; Tilt, C. Sustainable development goal disclosures: Do they support responsible consumption and production? *J. Clean. Prod.* 2020, 246, 118989.
2. Leal Filho, W.; Azul, A.M.; Brandli, L.; Özuyar, P.G.; Wall, T. Responsible Consumption and Production. *Encyclopedia of the UN Sustainable Development Goals*; Springer: Cham, Switzerland, 2020.
3. Katila, P.; Colfer, C.J.P.; de Jong, W.; Galloway, G.; Pacheco, P.; Winkel, G. SDG 12: Responsible Consumption and Production—Potential Benefits and Impacts on Forests and Livelihoods. *Sustainable Development Goals: Their Impacts on Forests and People*; Cambridge University Press: Cambridge, UK, 2019; pp. 386–418.
4. Franco, I.B.; Newey, L. SDG 12 Responsible Consumption and Production. In *Actioning the Global Goals for Local Impact*. Science for Sustainable Societies; Franco, I., Chatterji, T., Derbyshire, E., Tracey, J., Eds.; Springer: Singapore, 2020.
5. Jubin, J.J.; Clare, D.; Tim, M.; Stephen, S. Synergistic Interactions of SDGs in Food Supply Chains: A Review of Responsible Consumption and Production. *Sustainability* 2021, 13, 8809.
6. Whitson, J.; French, M. Productive play: The shift from responsible consumption to responsible production. *J. Consum. Cult.* 2021, 21, 14–33.
7. Ameli, M.; Esfandabadi, Z.S.; Sadeghi, S.; Ranjbari, M.; Zanetti, M.C. COVID-19 and Sustainable Development Goals (SDGs): Scenario analysis through fuzzy cognitive map modeling. *Gondwana Res.* 2022, in press.
8. Biasutti, M.; Frate, S. A validity and reliability study of the Attitudes toward Sustainable Development scale. *Environ. Educ. Res.* 2017, 23, 214–230.
9. Messner, D.; Nakicenovic, N.; Zimm, C.; Clarke, G.; Rockström, J.; Aguiar, A.P.; Boza-Kiss, B.; Campagnolo, L.; Chabay, I.; Collste, D.; et al. The Digital Revolution and Sustainable Development: Opportunities and Challenges-Report Prepared by the World in 2050 Initiative; International Institute for Applied Systems Analysis (IIASA): Laxenburg, Austria, 2019.
10. Luers, B.A. The Missing SDG: Ensure the Digital Age Supports People, Planet, Prosperity & Peace; Inter Press Service: Rome, Italy, 2020; pp. 7–8.
11. Alfonso, V.; Boar, C.; Frost, J.; Gambacorta, L.; Liu, J. E-commerce in the pandemic and beyond. *BIS Bull.* 2021, 36, 1–5.

12. Liu, K.; Liu, B.; Xu, H.; He, Y.; Cao, Y. Research on E-Commerce Live Broadcasts Helping Poverty Alleviation under the Influence of the COVID-19: Take Xinhua County, Hunan Province as an Example. In Proceedings of the 2nd International Conference on Economic Management and Model Engineering (ICEMME), Chongqing, China, 20–22 November 2020; pp. 858–865.
13. Guo, H.; Liu, Y.; Shi, X.; Chen, K.Z. The role of e-commerce in the urban food system under COVID-19: Lessons from China. *China Agric. Econ. Rev.* 2020, 13, 436–455.
14. Salem, M.A.; Nor, K.M. The effect of COVID-19 on consumer behaviour in Saudi Arabia: Switching from brick and mortar stores to E-Commerce. *Int. J. Sci. Technol. Res.* 2020, 9, 15–28.
15. Addo, P.C.; Jiaming, F.; Kulbo, N.B.; Liangqiang, L. COVID-19: Fear appeal favoring purchase behavior towards personal protective equipment. *Serv. Ind. J.* 2020, 40, 471–490.
16. Chen, C.; Hu, Y.; Lu, Y.; Hong, Y. Everyone Can Be a Star: Quantifying Grassroots Online Sellers' Live Streaming Effects on Product Sales. In Proceedings of the 52nd Hawaii International Conference on System Sciences, Grand Wailea, HI, USA, 8–11 January 2019; pp. 2548–2557.
17. Cai, J.; Wohn, D.Y.; Mittal, A.; Sureshbabu, D. Utilitarian and Hedonic Motivations for Live Streaming Shopping. In Proceedings of the 2018 ACM International Conference on Interactive Experiences for TV and Online Video, Newark, NJ, USA, 26–28 June 2018.
18. Chen, A.; Lu, Y.; Wang, B. Customers' purchase decision-making process in social commerce: A social learning perspective. *Int. J. Inf. Manag.* 2017, 37, 627–638.
19. Chen, C.C.; Lin, Y.C. What drives live-stream usage intention? The perspectives of flow, entertainment, social interaction, and endorsement. *Telemat. Inform.* 2018, 35, 293–303.
20. Hilvert-Bruce, Z.; Neill, J.T.; Sjöblom, M.; Hamari, J. Social motivations of live-streaming viewer engagement on Twitch. *Comput. Hum. Behav.* 2018, 84, 58–67.
21. Hong, Z.; Yi, L. Research on the influence of perceived risk in consumer on-line purchasing decision. *Phys. Procedia* 2012, 24, 1304–1310.
22. Gajewski, A.S. A Qualitative Study of How Facebook Storefront Retailers Convert Fans to Buyers. Ph.D. Dissertation, Walden University, Minneapolis, MN, USA, 2013.
23. Leeraphong, A.; Sukrat, S. How Facebook Live Urge SNS Users to Buy Impulsively on C2C Social Commerce? In Proceedings of the 2nd International Conference on E-Society, E-Education and E-Technology, Taipei, Taiwan, 13–15 August 2018; pp. 68–72.
24. Huang, Z.; Benyoucef, M. The effects of social commerce design on consumer purchase decision-making: An empirical study. *Electron. Commer. Res. Appl.* 2017, 25, 40–58.
25. Scheibe, K.; Fietkiewicz, K.J.; Stock, W.G. Information Behavior on Social Live Streaming Services. *J. Inf. Sci. Theory Prat.* 2016, 4, 6–20.
26. Skjuve, M.; Brandtzaeg, P.B. Facebook live: A mixed-methods approach to explore individual live streaming practices and motivations on Facebook. *Interact. Comput.* 2019, 31, 589–602.
27. Just, M.A.; Carpenter, P.A. Eye fixations and cognitive processes. *Cogn. Psychol.* 1976, 8, 441–480.
28. Just, M.A.; Carpenter, P.A. A theory of reading: From eye fixations to comprehension. *Psychol. Rev.* 1980, 87, 329–354.
29. Hopkins, E. Machine Learning Tools, Algorithms, and Techniques. *J. Self-Gov. Manag. Econ.* 2022, 10, 43–55.
30. Klietnik, T.; Kovalova, E.; Lăzăroiu, G. Cognitive decision-making algorithms in data-driven retail intelligence: Consumer sentiments, choices, and shopping behaviors. *J. Self-Gov. Manag. Econ.* 2022, 10, 30–42.
31. Nica, E.; Sabie, O.M.; Mascu, S.; Luțan, A.G. Artificial Intelligence Decision-Making in Shopping Patterns: Consumer Values, Cognition, and Attitudes. *Econ. Manag. Financ. Mark.* 2022, 17, 31–43.
32. Lai, M.L.; Tsai, M.J.; Yang, F.Y.; Hsu, C.Y.; Liu, T.C.; Lee, S.W.Y.; Li, M.H.; Chiou, G.L.; Liang, G.C.; Tsai, C.C. A review of using eye-tracking technology in exploring learning from 2000 to 2012. *Educ. Res. Rev.* 2013, 10, 90–115.
33. Rayner, K. Eye movements in reading and information processing: A 20-year study. *Psychol. Bull.* 1998, 124, 372.
34. Rayner, K.; Chace, K.H.; Slattery, T.J.; Ashby, J. Eye movements as reflections of comprehension process in reading. *Sci. Stud. Read.* 2006, 10, 241–255.
35. Rayner, K. Eye movements and attention in reading, scene perception, and visual search. *Q. J. Exp. Psychol.* 2009, 62, 1457–1506.

36. Vernet, M.; Kapoula, Z. Binocular motor coordination during saccades and fixations while reading: A magnitude and time analysis. *J. Vis.* 2009, 9, 2.
37. Nyström, M.; Holmqvist, K. An adaptive algorithm for fixation, saccade, and glissade detection in eye tracking data. *Behav. Res. Methods* 2010, 42, 188–204.
38. Agnieszka, A.T. Basic terminology of eye-tracking research. *Appl. Linguist. Pap.* 2018, 25, 123–132.
39. Hessels, R.S.; Niehorster, D.C.; Nyström, M.; Andersson, R.; Hooge, I.T. Is the eye-movement field confused about fixations and saccades? A survey among 124 researchers. *R. Soc. Open Sci.* 2018, 5, 180502.
40. Heller, D.; Müller, H. On the Relationship between Saccade Size and Fixation Duration in Reading. In *Eye Movements and Psychological Functions*; Routledge: London, UK, 2021; pp. 287–302.
41. Stuart, S.; Hickey, A.; Vitorio, R.; Welman, K.; Foo, S.; Keen, D.; Godfrey, A. Eye-tracker algorithms to detect saccades during static and dynamic tasks: A structured review. *Physiol. Meas.* 2019, 40, 02TR01.
42. Tanke, N.; Barsingerhorn, A.D.; Boonstra, F.N.; Goossens, J. Visual fixations rather than saccades dominate the developmental eye movement test. *Sci. Rep.* 2021, 11, 1162.
43. Hooge, I.T.; Niehorster, D.C.; Nyström, M.; Andersson, R.; Hessels, R.S. Fixation classification: How to merge and select fixation candidates. *Behav. Res. Methods* 2022, 1–12.
44. Kang, K.; Lu, J.; Guo, L.; Li, W. The dynamic effect of interactivity on customer engagement behavior through tie strength: Evidence from live streaming commerce platforms. *Int. J. Inf. Manag.* 2021, 56, 102251.
45. Ho, H.F. The effects of controlling visual attention to handbags for women in online shops: Evidence from eye movements. *Comput. Hum. Behav.* 2014, 30, 146–152.
46. Ho, H.F.; Chen, G.A.; Vicente, C.T. Impact of Misplaced Words in Reading Comprehension of Chinese Sentences: Evidences from Eye Movement and Electroencephalography. In *Proceedings of the 23rd International Conference on Computers in Education(ICCE 2015)*, Hangzhou, China, 30 November–4 December 2015; pp. 573–579.
47. Pang, J. E-Commerce Business Model Innovation Under the Background of Internet Celebrity Economy. In *Proceedings of the 6th International Conference on Financial Innovation and Economic Development*, Sanya, China, 29–31 January 2021; pp. 513–519.
48. Geng, R.; Wang, S.; Chen, X.; Song, D.; Yu, J. Content marketing in e-commerce platforms in the internet celebrity economy. *Ind. Manag. Data Syst.* 2020, 120, 464–485.
49. Djafarova, E.; Rushworth, C. Exploring the credibility of internet celebrities' Instagram profiles in influencing the purchase decisions of young female users. *Comput. Hum. Behav.* 2017, 68, 1–7.
50. Kang, J.; Tang, L.; Fiore, A.M. Enhancing consumer-brand relationships on restaurant Facebook fan pages: Maximizing consumer benefits and increasing active participation. *Int. J. Hosp.* 2014, 36, 145–155.
51. Zorah, H.B.; James, T. Neill Social motivations for viewer engagement on Twitch live streams. *Comput. Hum. Behav.* 2018, 84, 58–67.
52. Sanders, M.S.; McCormick, E.J. *Human Factors in Engineering and Design*; McGraw-Hill: New York, NY, USA, 1987.
53. Viviani, P. Eye movements in visual search: Cognitive, perceptual, and motor control aspects. *Rev. Oculomot. Res.* 1990, 4, 353–393.
54. Cornsweet, T.N. New technique for measuring small eye movements. *J. Opt. Soc. Am.* 1958, 48, 808–811.
55. Valliappan, N.; Dai, N.; Steinberg, E.; He, J.; Rogers, K.; Ramachandran, V.; Navalpakkam, V. Accelerating eye movement research via accurate and affordable smartphone eye tracking. *Nat. Commun.* 2020, 11, 4553.
56. Duchowski, A.T. A breadth-first survey of eye-tracking applications. *Behav. Res. Methods Instrum. Comput.* 2002, 34, 455–470.
57. Henderson, J.M.; Hollingworth, A. Advanced scene awareness. *Annu. Rev. Psychol.* 1999, 50, 243–271.
58. Klaib, A.F.; Alsrehin, N.O.; Melhem, W.Y.; Bashtawi, H.O.; Magableh, A.A. Eye tracking algorithms, techniques, tools, and applications with an emphasis on machine learning and Internet of Things technologies. *Expert Syst. Appl.* 2021, 166, 114037.
59. Carter, B.T.; Luke, S.G. Best practices in eye tracking research. *Int. J. Psychophysiol.* 2020, 155, 49–62.
60. Dixon, B.; Grimshaw, G.; Ormsby, D.; Dixon, A. Eye tracking women's preferences or men's body type. *Evol. Hum. Behav.* 2014, 35, 73–79.
61. Wu, S.C. Using Eye-Tracking Technology to Examine the Relationship between Landscape Preference, Attention Recovery, Image Features and Number of Gazes. Ph.D. Dissertation, Feng Chia University Civil and Hydraulic

62. Galvan, A. Neural plasticity of development and learning. *Hum. Brain Mapp.* 2010, 31, 879–890.
63. Phillips, D.C.; Soltis, J.F. *Perspectives on Learning*; Teachers College Press: New York, NY, USA, 2009.
64. Mayer, R.E. *Multimedia Learning*; Cambridge University Press: Cambridge, UK, 2001.
65. Yang, F.Y.; Chang, C.Y.; Chien, W.R.; Chien, Y.T.; Tseng, Y.H. Tracking learners' visual attention during a multimedia presentation in a real classroom. *Comput. Educ.* 2013, 62, 208–220.
66. Chen, H.C.; Lai, H.D.; Chiu, F.C. Eye tracking technology for learning and education. *Sci. Res. Educ.* 2010, 4, 39–68.
67. Goldberg, H.J.; Kotval, X.P. Computer interface evaluation using eye movements: Methods and constructs. *Int. J. Ind. Ergon.* 1999, 24, 631–645.
68. Van Gog, T.; Scheiter, K. Eye tracking as a tool to study and enhance multimedia learning. *Learn. Instr.* 2010, 20, 95–99.
69. Yildirim, B.; Sahin-Topalcengiz, E.; Arıkan, G.; Timur, S. Using virtual reality in the classroom: Reflections of STEM teachers on the use of teaching and learning tools. *J. Educ. Sci. Environ. Health* 2020, 6, 231–245.
70. Zhang, X.B.; Yuan, S.M.; Chen, M.D.; Liu, X.L. A complete system for analysis of video lecture based on eye tracking. *IEEE Access* 2018, 6, 49056–49066.
71. Pan, T.W.; Tsai, M.J. Eye-Tracking Analyses of Text-and-Graphic Design Effects on E-Book Reading Process and Performance: "SPANISH Color Vocabulary" as an Example. In *Proceedings of the 22nd International Conference on Computers in Education (ICCE2014)*, Nara, Japan, 30 November–4 December 2014; pp. 494–498.
72. Leung, C.Y. Can Japanese EFL Learners "See" before They "Read"? In *2014 Studies in Japan Association for Language Education and Technology, Kansai Chapter; Methodology Special Interest Groups (SIG)*: Kobe, Japan, 2014; Volume 5, pp. 16–27.
73. Was, C.; Sansosti, F.; Morris, B. *Eye-Tracking Technology Applications in Educational Research*; IGI Global: Hershey, PA, USA, 2016.
74. Hamilton, W.A.; Garretson, O.; Kerne, A. Twitch Streaming: Fostering a Participatory Gaming Community in Live Mixed Media. In *Proceedings of the 32nd ACM Annual Conference on Human Factors in Computing Systems*, Toronto, ON, Canada, 26 April–1 May 2014; pp. 1315–1324.
75. Liu, H.C.; Chuang, H.H. An examination of cognitive processing of multimedia information based on reviewers' eye movements. *Interact. Learn. Environ.* 2011, 19, 503–517.
76. Liu, H.C.; Lai, M.L.; Chuang, H.H. Using eye-tracking technology to investigate the redundant effect of multimedia web pages on viewers' cognitive processes. *Comput. Hum. Behav.* 2011, 27, 2410–2417.
77. Tsai, M.J.; Huang, L.J.; Hou, H.T.; Hsu, C.Y.; Chiou, G.L. Visual behavior, flow and achievement in game-based learning. *Comput. Educ.* 2016, 98, 115–129.
78. Romero-Hall, E.; Watson, G.S.; Adcock, A.; Bliss, J.; Adams Tufts, K. Simulated environments with animated agents: Effects on visual attention, emotion, performance, and perception. *J. Comput. Assist. Learn.* 2016, 32, 360–373.
79. Liu, W.; Yu, M.; Fan, Z.; Xu, J.; Tian, Y. Visual Attention Based Evaluation for Multiple-Choice Tests in E-Learning Applications. In *Proceedings of the 2017 IEEE Frontiers in Education Conference (FIE)*, Indianapolis, IN, USA, 18–21 October 2017; pp. 1–6.
80. Klein, P.; Dengel, A.; Kuhn, J. Students' Visual Attention While Solving Multiple Representation Problems in Upper-Division Physics. In *Positive Learning in the Age of Information*; Zlatkin-Troitschanskaia, O., Wittum, G., Dengel, A., Eds.; Springer VS: Wiesbaden, Germany, 2018; pp. 67–87.
81. Wang, C.C.; Hung, J.C. Comparative analysis of advertising attention to Facebook social network: Evidence from eye-movement data. *Comput. Hum. Behav.* 2019, 100, 192–208.
82. Wang, C.C.; Hung, J.C.; Chen, H.C. How Prior Knowledge Affects Visual Attention of Japanese Mimicry and Onomatopoeia and Learning Outcomes: Evidence from Virtual Reality Eye Tracking. *Sustainability* 2021, 13, 11058.
83. Kaakinen, K.J.; Hyönä, J.; Keenan, M.J. How prior knowledge, working memory capacity, and information relevance affect fixation in expository texts. *J. Exp. Psychol. Learn. Mem. Cogn.* 2003, 29, 447–457.
84. Clay, V.; König, P.; Koenig, S. Eye tracking in virtual reality. *J. Eye Mov. Res.* 2019, 12.
85. Zhao, D.; Lucas, J. Virtual reality simulation for construction safety promotion. *Int. J. Inj. Control Saf. Promot.* 2015, 22, 57–67.

86. Teng, Y.Y.; Chou, W.C.; Cheng, M.T. Learning immunology in a game: Learning outcomes, the use of player characters, immersion experiences and visual attention distributions. *J. Comput. Assist. Learn.* 2021, 37, 475–486.
87. Son, M.; Kim, J.; Kim, H. Viewers' Visual Attention on Subtitles in Home Shopping Broadcasts: The NS Home Shopping Channel. *Arch. Des. Res.* 2022, 35, 217–235.

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