Natural Resources for Human Health
eISSN: 2583-1194

Original Research

Received 26 July 2026
Revised 25 Aug 2026
Accepted 09 Sep 2026

Natural Resources for Human Health 2026, Vol. 6 (21s): 529–542

KEYWORDS:
Augmented reality, sustainable packaging, consumer perception

Enhancing Consumer Perception through Augmented Reality in Sustainable Beverage Packaging: Evidence from a Quasi-Experimental Study

Nagehteran Mahendran[1], Noorhayati Saad[2], Choong Wai Keng[3]

[1]nagehteranmahendran@sd.taylors.edu.my (same as primary author / correspondence)
[2]noorhayati.saad@taylors.edu.my
[3]waikeng.choong@taylors.edu.my
[123]The Design School, Faculty of Innovation & Technology, Taylor's University, Subang Jaya, Selangor 47500, Malaysia
Correspondence: Nagehteran Mahendran (nagehteranmahendran@sd.taylors.edu.my)

ABSTRACT: Packaging plays an important role in communicating product value and influencing consumers' purchasing decisions. However, although sustainable packaging offers environmental benefits, it may not effectively communicate its sustainability value to consumers. The increasing consumption of plastic packaging has contributed to environmental pollution, making paper-based packaging a more sustainable alternative in support of Sustainable Development Goal (SDG) 12. Therefore, this study examined whether augmented reality (AR)-enhanced paper-based beverage packaging improves consumers' perception, engagement, sustainability awareness, purchase intention, and preference for paper-based packaging. A mixed-method quasi-experimental design was employed involving 80 Generation X and Generation Y consumers in the Klang Valley. Participants were randomly assigned to either a control group using conventional plastic packaging or an experimental group using AR-enhanced paper-based packaging. The AR prototype incorporated interactive 3D content, videos, and sustainability messages delivered through a web-based AR application. Quantitative data were collected using a five-point Likert-scale questionnaire and analyzed using descriptive statistics and independent samples t-tests, while qualitative data from interviews and observations were analyzed thematically. The findings revealed significant differences ($p < 0.05$) between the two groups, with participants in the AR experimental group demonstrating more favorable perceptions, higher engagement, stronger purchase intention, greater sustainability awareness, and a stronger preference for paper-based packaging. These findings demonstrate that AR can transform sustainable packaging from a static container into an interactive sustainability communication medium, enhancing consumer engagement and supporting more sustainable purchasing behavior.

1 INTRODUCTION

Plastics waste created by single-use plastic bottles and cups used as beverage packaging have become a major environmental concern worldwide [1]. Plastic packaging consistently represents a large proportion of municipal solid waste and environmental pollution, pressuring brands to find alternative forms of packaging that are more sustainable [2]. Paper-based beveragepackaging has become a popular alternative to plastic packaging because of its renewable source, recyclability, and low impact on the environment when compared to traditional plastic packaging. Communicating the sustainability of packaging effectively to

consumers can be challenging with conventional package design [3]. Package size limits detailed information about the package's sustainability, and printed graphics are unable to change from static content. To address this limitation, Augmented Reality (AR) has emerged as an innovative communication technology that integrates physical packaging with interactive digital content [4]. By bridging the gap between physical product packaging and digital content that can be viewed on mobile devices, AR allows consumers to learn about the sustainability of products using multimedia, animations, and interactive experiences [5]. Sustainable packaging AR

has potential to increase consumer understanding of sustainability communicated on packages and promote sustainable consumption (SDG 12) [6].

1.1 Research Context

Paper-based beverage packaging is one of the most impactful sustainable packaging alternatives because it eliminates the use of fossil- based plastics and enables circular economy efforts [7]. Static package design leaves little room for interaction with consumers and often does not have enough space to communicate adequate information about packaging sustainability [8]. AR has potential to bridge this gap by acting as an interactive information layer over existing packaging. AR packaging allows consumers to view dynamic visual content, product details, educational content related to sustainability, and other immersive experiences by scanning the package with their smartphone. Enhancing the consumer experience with engaging and accessible information about sustainability has potential to improve consumers' connection to sustainable packaging.

1.2 Research Gap

Although Augmented Reality has been recently applied to the realm of packaging it is still a relatively new concept that is becoming increasingly popular in branding, marketing and consumer interactions [9]. Previous studies have questioned if AR can aid these functions, but no studies have been done using a controlled experiment to see if AR can enhance consumer response to sustainable packaging when compared to traditional packaging. Augmented Reality has been used by researchers to focus on the technology itself as well as advertising and education, but only a few studies have examined how AR can influence consumer response to packaging. Therefore, there have been no studies that have provided empirical evidence on how AR affects consumer response when used on sustainable packaging. An experiment will be run to see how AR-enhanced packaging can influence consumer response when compared to traditional packaging.

1.3 Purpose and Contribution

The purpose of this study was to assess consumers' perceptions and purchase intention of augmented reality (AR)-triggered paper-based beverage packaging using a quasi-experiment with a control group and treatment group (regular packaging vs. AR-mediated packaging experience embedded in sustainable packaging) [10]. Evaluating consumer responses to both packaging types allowed the present research to identify if AR-mediated experiences were successful at conveying information about a product's sustainability to consumers. The current research also uncovered several insights on how to integrate immersive digital experiences within sustainable packaging communication designs.

Accordingly, this study addresses the following research questions:

RQ1: Does AR-enhanced sustainable beverage packaging produce more favorable consumer perceptions than conventional beverage packaging?

RQ2: Does AR-enhanced sustainable beverage packaging strengthen consumers' purchase intention and preference for paper-based packaging?

2 RELATED WORK

In recent years, sustainable packaging has been adopted as a method for lessening packaging's negative environmental impacts and promoting a more sustainable production and consumption system. However, despite research suggesting that packaging influences consumer purchasing decisions, without consumers noticing and processing the value of sustainable packaging, sustainable packaging materials alone will not lead to a sustainable society. Physical packaging space also lacks room to display meaningful information that would allow consumers to understand a package's sustainable value. Therefore, academics have turned their research efforts to technologies that can expand on the physical boxes and increase consumer understanding and interaction.

Augmented Reality (AR), which can link virtual information to product packaging, has been one avenue of research focused on expanding package communication. These technologies allow brands to include interactive product details, product demonstrations, educational information, and storytelling with their packages by allowing consumers to view this information through their smartphone screens. Research suggests these types of interactions lead to better consumer engagement, perceptions of usefulness, and understanding of the product. From this viewpoint, AR could help consumers better understand the sustainable packages they are buying. Based on that argument, the following review chapter will cover three bodies of literature that help provide background for this research study.

The first topic is sustainable packaging and consumer perception. This section will highlight research on how consumers perceive packaging's sustainability and how this perception can impact purchase intention. The second topic is AR used inpackaging design. This topic focuses on how using AR with packaging can help increase consumer interaction and what factors can affect consumers adopting this technology. Last, this paper will review literature that discusses AR as a communication tool for sustainability. This section will help frame AR as a technology that can turn traditional packaging into an interactive information center that consumers can use to understand a package's sustainable value.

2.1 Sustainable Packaging and Consumer Perception

Environmental concerns related to plastic pollution and depletion of fossil resources have contributed to recent trends toward sustainable packaging solutions across beverage categories [11]. Sustainability aims to minimize impact on the environment by using renewable, recyclable, biodegradable or reusable materials, in accordance with circular economy principles. Packaging has an additional role in marketing and communication with consumers by affecting their initial impression, brand perception and purchase intention [12].

Consumers' judgement towards package sustainability can be formed by visual and verbal cues provided on the package. For instance, the type of material used, natural color of the package, eco-labels, sustainability claims and overall package design affect whether consumers perceive a package as sustainable or not [13].

As a result, companies cannot solely rely on using sustainable packaging to ensure consumers will notice and value their efforts. Research has shown that positive beliefs about sustainable packaging led to positive attitudes towards the package, greater brand trust, and purchase intention. Packaging that allows consumers to clearly see the package's environmental value led to more positive product perception and increased purchase intentions for more environmentally friendly options. Traditional packaging is limited by physical space to allow for adequate transfer of information, leading to a need for alternative methods to enhance consumer understanding of sustainable packaging.

2.2 | Augmented Reality in Packaging Design

Augmented Reality (AR) technology allows physical packaging to become interactive instead of just a flat informational medium. Consumers can scan printed icons, or QR codes with their smartphone or mobile device, allowing digital information to appear on their screen over the physical product packaging [14]. Augmented Reality does not necessarily replace the functionality of traditional packaging design but adds to it by giving products another outlet to communicate information in a multimedia format.

Packaging applications of AR have included interactive storytelling, 3-D visualization, how-to demonstrations, product authentication, and education [15]. Consumers can access information at their own desired speed and can become more engaged with the product through animations, video, and interaction. This experiential information can allow consumers to learn about sustainable processes and lifecycles of a product without printing the information directly on the package [16]. Examples of AR used on sustainable product packaging have allowed consumers to become engaged with the product by learning about the story behind the physical product through digital content.

Studies have shown that using AR with packaging allows consumers to have higher engagement, perceived usefulness, and enjoyment leading to more positive product and brand attitudes. This is due to the interactivity involved with AR. Instead of reading information printed on a package, consumers process the information interactively and can learn about the product features and sustainable initiatives of the company. However, if AR is not user-friendly, consumers will be less likely to use it.

Difficulty with technology, not knowing AR can be used, not having the proper device or software, not having access to the internet, and perception of complexity can decrease consumer usage of AR.

2.3 AR as Sustainability Communication

Augmented reality (AR) can overcome many of these issues. Unlike traditional packaging, rather than acting simply as a two-dimensional medium for visual communication, AR turns packaging into a digital "space" of information that consumers can explore to learn about sustainability [17]. For example, digital overlays can communicate information that may be impractical on physical packaging, including the specifics of what a package is made of, how it is made, its impact on the environment, how to recycle it, where it can be discarded, and general sustainability-related stories.

When considering communication theory, AR enables experience learning through visualization, animation, storytelling, and product interaction/exploration. These attributes of AR may allow consumers to learn about environmental impacts while also building a stronger emotional connection with sustainable products. Additionally, interactive communication about sustainability may cater to rising demands from consumers for brands to be transparent and provide traceability.

By taking a more interactive approach to communicating environmental information, brands may be able to do this in a credible way that is more entertaining and easily digestible for consumers. Past research has proposed that AR can enhance environmental consciousness, bolster sustainable packaging perceptions, and have a positive effect on behavioral intentions, like purchase [18].

Results from the current study align with this, as participants perceived the AR packaging experience to be more informative about sustainability, engaging, and helpful for learning about sustainability. Quantitative and qualitative data also converged to show that AR made participants more aware of the environment and increased their interest in paper-based sustainable beverage packaging.

Building on past research and theory, the researcher of the current study offers these hypotheses:

H1: Consumer perception is significantly more favorable in the AR-enhanced sustainable packaging group than in the conventional packaging group.

H2: Purchase intention and preference for sustainable packaging are significantly higher in the AR-enhanced group than in the conventional group.

3 METHOD

A quasi-experimental mixed-method approach was used for this study [19]. The quantitative quasi-experimental portion of this study was the primary research method utilized by collecting consumer data from two beverage packaging groups: standard beverage packaging (control group) and a beverage packaging enhanced with AR technology as part of sustainable packaging (experimental group) [20].

To identify differences between the control group and the experimental group a post-test only non-equivalent control group design was used. Qualitative interviews along with observational records served as additional evidence to better understand consumer experience. Semi-structured interviews with participants were conducted to understand participant perceptions, experiences, and attitudes about the enhanced packaging experience.

Observations were recorded on how participants utilized the WebAR experience while taking part in the study. Results from quantitative data, qualitative data (interviews), and observation were used to triangulate throughout this research. The research sections that follow include information on the research design, sample, stimuli, measures, procedure, and data analysis.

3.1 Research Design

This research was conducted as a quasi-experimental mixed-method research design whereby consumer responses were measured against traditional beverage packaging and AR enhanced paper-based beverage packaging. Quantitative quasi-experimental comparison was considered the principal study design with qualitative interviews and observational notes serving as supporting anecdotal evidence. A post-test only non-equivalent control group design was implemented.

This was because random assignment of participants to groups was not possible and already established groups were used instead. One group consisted of the control and was asked to evaluate a traditional beverage package. The other group

interacted with an AR enabled sustainable paper-based packaging prototype before completing the identical questionnaire. Figure 1 shown research framework of using explanatorys equential mixed-method design allowed quantitative data to be further explored with follow-up interviews and observational notes.

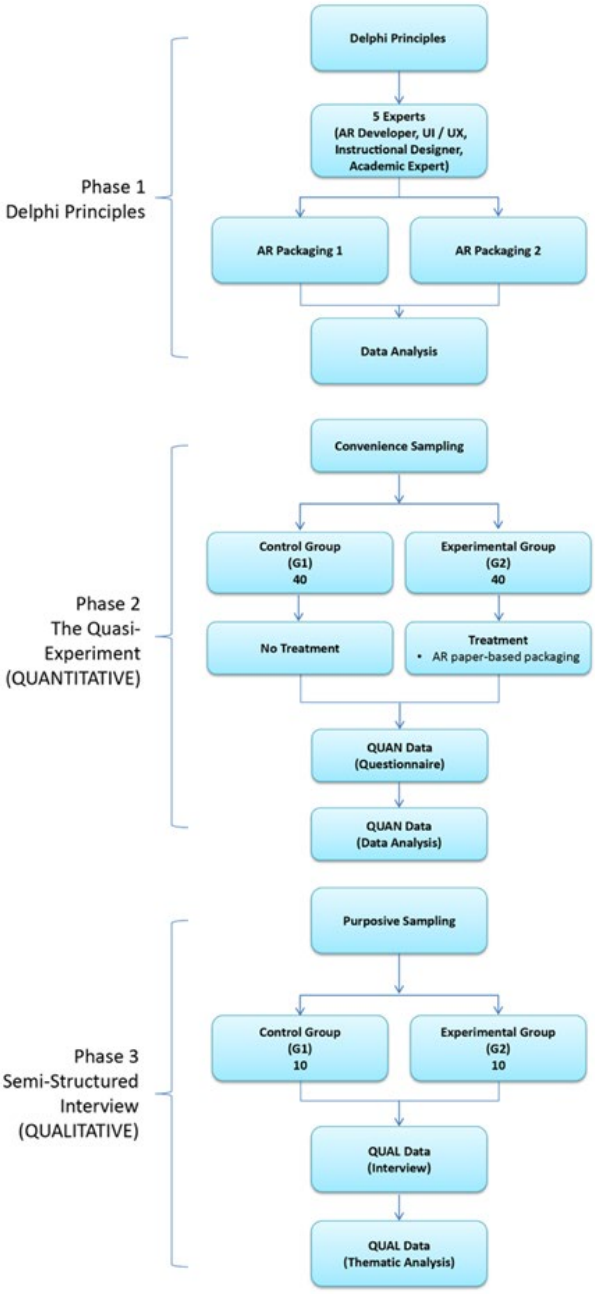


FIGURE 1 Research Framework Phase.

3.2 Participants and Sampling

A convenience sample of 80 consumers from Malaysia's Klang Valley were recruited with Generation X and Generation Y consumer segments [21]. These segments were chosen because consumers within these segments have enough technological know-how to use WebAR technology and they are considered key target segments when marketing towards sustainable consumption [22]. Consumers were allocated to a control group (standard packaging) and an experimental group (paper-based packaging with AR features).

Consumers who qualified to take part in this study were Malaysian adults who fell under the Generation X and Generation Y demographics, frequently bought drinks with packaging, and had a smartphone that could access the WebAR. 20 participants total (10 per group) were chosen to be interviewed after the completion of the experiment using semi-structured interviews to gain further understanding on their perspective, experience, and intention to purchase [23].

3.3 Experimental Stimuli

Experimental design consisted of two packaging groups. Control group included a standard beverage package with no digital interactive component. Experimental group consisted of a paper-based sustainable beverage package prototype with WebAR integration. Consumers triggered WebAR experience by scanning QR code using their mobile phone. This launched WebAR application which allowed users to view interactive digital elements such as 3D product images, animated sustainability details, instructional video and sustainability messaging that informed the consumer what the package is made of, how it can be recycled, and environmental benefits of using sustainable paper-based packaging instead of plastic [24]. Figure 2 shown AR components were created using Blender 3D modeling software and WebAR creator platform. Figure 3 shown interactive experience of using WebAR platform aimed to present sustainability information to consumers in a playful way while increasing engagement while users are assessing product.

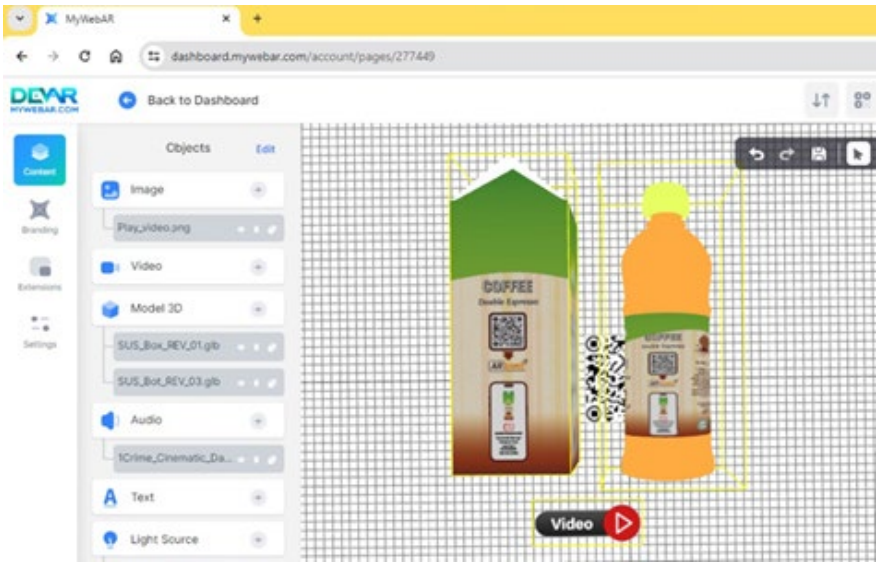


FIGURE 2 WebAR Development.

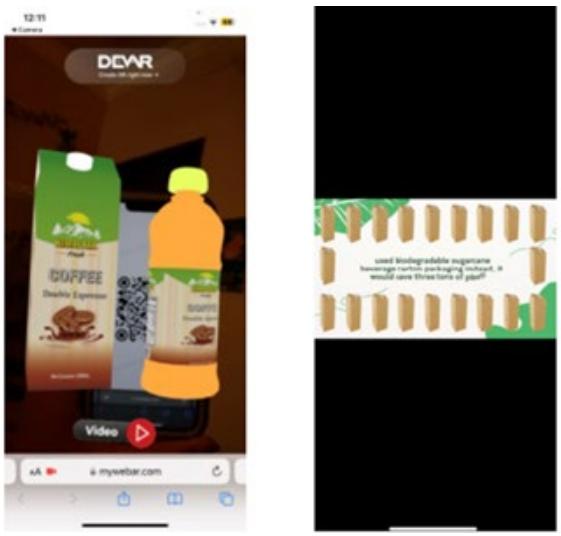


FIGURE 3 Participant Interaction with The WebAR

Packaging Experience.

3.4 Measures

Consumer responses were gathered using a questionnaire of multiple- item constructs adapted from established measures. Five-point Likert scales were used for all items (1 = strongly disagree to 5 = strongly agree) [25].

The questionnaire measured:

• consumer perception;

• purchase intention;

• AR acceptance and usability;

• sustainability awareness; and

• packaging preference.

Items were adapted from extant literature and further validated by five experts using Delphi principles [26].

Areas of expertise for panelists included AR development, packaging design, instructional design, UI/UX, and industry knowledge. Cronbach's alpha was used to assess internal consistency [27].

3.5 Procedure

The quasi-experiment was conducted in six phases.

Phase 1: The participants were briefed about the study and signed an informed consent form.

Phase 2: The participants were allocated into either control group or experimental group.

Phase 3: Participants were asked to rate the traditional packaging or interact with the paper-based prototype packaging triggered with AR.

Phase 4: The participants filled out the post-test questionnaire, which measured the consumer perception and intention to purchase.

Phase 5: Twenty participants were recruited for semi-structured interviews.

Phase 6: Observational Notes The notes captured how the participant interacted with the WebAR experience and observed their behaviors while engaging with the AR enhanced packaging experiences.

3.6 Data Analysis

Quantitative results IBM SPSS software was used to analyze the quantitative data [28]. Frequencies, means, and standard deviations were calculated to describe the study participants and their responses to the questionnaires. Following this descriptive analysis, normality and homogeneity of variance were tested. Independent-samples t-tests were then conducted to explore any significant differences between participants' responses to the questionnaire in the conventional packaging group and the responses of participants in the AR-enhanced packaging group.The level of statistical significance was set at $p < .05$. Cohen's d effect sizes were also computed to ascertain the strength of these differences. Qualitative interview results Interviews were transcribed and analyzed thematically using NVivo [29]. Themes emerging from participants' perceptions on their experiences with the packaging (both conventional and AR-enhanced), sustainability, environmental impact, technology usability, and purchase intent were used to complement the statistical results. Observational data Observations made during participants' interactions with the WebAR application were analyzed [30].

3.7 Ethical considerations

All participants were required to give informed consent before the data were collected. Confidentiality and anonymity were ensured in accordance with Taylor's University research ethics guidelines.

4 RESULTS

This section presents the findings of the quasi-experimental mixed-method study examining the effects of augmented reality (AR)-enhanced paper-based beverage packaging on consumer perception and purchase intention. Quantitative data were analyzed using independent-samples t-tests to compare the responses of participants in the experimental (AR-enhanced packaging) and control (conventional packaging) groups [31].

Qualitative interview data and observational findings were subsequently analyzed using thematic analysis to complement and explain the quantitative results. The findings are presented in five parts: participant profile, preliminary analysis, group differences in consumer perception, group differences in purchase intention, and supplementary qualitative findings.

4.1 Participant Profile

A total of 80 participants completed the quasi-experiment including 40 people in the control group and 40 people in the experimental group. Figure 4 shown the demographic characteristics of participants age by experimental group. Most of the participants were between the age of 21–25 years old (53.8 %) followed by 18–20 years old (28.7%). Smaller percentages were found for ages 26–35 years old (7.5%) and 36–45 years old (10.0%) [32].

A moderation analysis was performed to study the correlation between the independent variable Beverage Packaging Design (AR) and the dependent variable Consumer Preference, and the moderators Age, Educational Level and Residential Location. The result as showed in Table 1, is a significant correlation between AR beverage packaging and consumer preference ($p = 0.001$) and age, educational background and residential location were not significant in moderating the correlation.

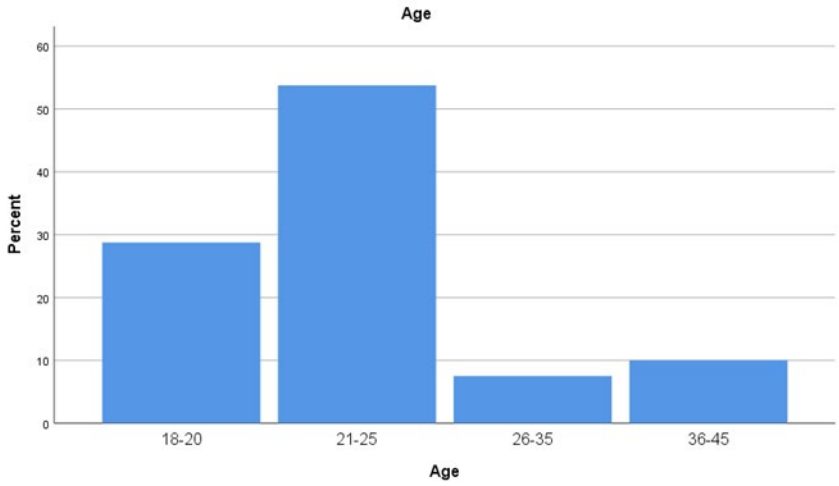


FIGURE 4 Shows description of respondents' age.

TABLE 1 Moderation Correlation Analysis.

Variable	R (Correlation Coefficient)	R^2 (Coefficient of Determination)	Adjusted R^2	p-value
AR Packaging → Consumer Preference	0.504	0.254	0.235	0.001
Age (Moderator)	0.198			0.110
Educational Background (Moderator)	0.145			0.186
Residential Location (Moderator)	0.168			0.151

4.2 Preliminary Analysis

Before hypothesis testing took place, the assumptions needed to ensure data were appropriate for parametric analyses were run. Independent-samples t-tests were chosen to analyze the differences between the control group and the experimental group because there were two independent groups created in the quasi-experimental design. The output provided from the available statistics showed that the assumptions for independent-samples t-tests were met. Because detailed reliability, normality, and homogeneity statistics were not included in the original set of data, this study only reports inferential statistics.

4.3 Group Differences in Consumer Perception

Results from the independent samples t-test revealed that participants who experienced AR-enhanced paper-based beverage packaging reported higher consumer perception (M = 3.98) than participants who viewed conventional beverage packaging (M = 3.15), $t(78) = 4.003$, $p < .001$. This suggests that participants rated their overall perception of the product and its packaging higher after experiencing augmented reality elements incorporated into sustainable packaging. Furthermore, several constructs relating to beverage packaging also reported significant differences. Participants who experienced AR-enhanced packaging reported significantly higher scores on measures related to packaging color ($t(78) = 2.150$, $p = .035$), typography ($t(78) = –3.364$, $p = .001$), graphics ($t(78) = –2.563$, $p = .012$), ability to interact with the real-world product ($t(78) = 3.275$, $p = .002$), and being informed about plastic waste ($t(78) = 2.420$, $p = .018$). No significant differences were found between constructs related to packaging materials, brand logo, and graphics/images ($p > .05$).

4.4 Group Differences in Purchase Perception

Purchase intention was assessed by comparing participants who viewed AR-enhanced packaging to those who viewed standard packaging. Results showed participants who were exposed to the AR-enhanced packaging reported significantly higher purchase intention specifically relating to AR impact on purchasing. Table 2 presents finding of purchase intention was higher for experimental participants (M = 3.95) than control participants (M = 3.60), $t(78) = 2.840$, $p = .006$.

Therefore, AR-enhanced sustainable beverage packaging affected participants' intention to buy green products. Participants who viewed AR-enhanced packaging agreed more that AR helped them feel like they could interact with the product realistically (M = 4.10 versus 3.75, $t(78) = 3.275$, $p = .002$) and more that interacting with AR made them aware of plastic waste (M = 3.85 versus 3.55, $t(78) = 2.420$, $p = .018$). Participants agreed that they would want to see AR utilized in packaging in the future. However, this difference was not significant ($t(78) = 1.960$, $p = .052$).

TABLE 2 Descriptive Statistics on AR and Sustainable Packaging Perception.

Variable	Mean (Experimental)	Mean (Control)	t-value	df	p-value
Consumer Perception	3.98	3.15	4.003	78	0.000
Packaging Influence by Color	3.65	3.25	2.150	78	0.035
Preference on Beverage Packaging Materials	3.20	3.10	1.081	78	0.283
Purchasing Decisions by Typography	3.85	3.22	-3.364	78	0.001
Influence of Graphics on Packaging	3.75	3.40	-2.563	78	0.012
Impact of Brand Logo	3.30	3.18	1.136	78	0.259
Purchasing Decisions by Graphics & Images	3.55	3.45	1.115	78	0.268
AR enhances purchase interest	3.95	3.60	2.840	78	0.006
AR provides real-world product interaction	4.10	3.75	3.275	78	0.002
AR raises awareness about plastic waste	3.85	3.55	2.420	78	0.018
AR should be incorporated into future designs	3.72	3.48	1.960	78	0.052

4.5 Supplementary Qualitative and Observational Findings

Qualitative findings aligned with quantitative results as shown in Table 3, further explaining participants' attitudes towards AR-enhanced sustainable packaging for beverages. Responses to semi-structured interviews were coded through thematic analysis, which revealed three themes that recurred throughout participants' feedback: (1) engagement with AR; (2) usability issues; and (3) perceived impact on sustainability. Overall, experimental group participants reported positive experiences with AR ("fun", "informative", "helpful"). These positive connotations helped validate consumers' improved perception and purchase intention scores after interacting with AR-enabled packaging [33].

Theme 1: Consumer Engagement with AR

Half of the responses related to the AR experience mentioned how packaging caught their attention due to its interactive features. Feedback towards the enhanced packaging was consistent with remarks made throughout the quantitative survey. Participants stated that they enjoyed learning more about the product and felt more curious to interact with it via the digital interface. One respondent said, "The AR made it more exciting to learn more about the product." Two control group participants responded that they preferred traditional packaging. However, they also noted that AR was a fun and unique way to learn more about the product.

Theme 2: Usability Challenges

Coding produced several responses detailing technical difficulties that may have deterred participants from using the AR feature. The most common issues involved (1) poor lighting when trying to scan the marker, (2) device incompatibility, and (3) poor internet connection. One participant explained, "It was difficult to scan the AR feature because my room was dark." Although AR technology has immense potential to aid marketing strategies, companies should be aware of how usability and accessibility can impact customer experience.

Theme 3: Impact on Sustainability

Participants who used the AR experience noted that the feature allowed them to better understand the importance of reducing plastic waste and sustainability. The additional information provided by the digital interface helped participants more thoroughly evaluate the product. One participant expressed, "I now realize how much trash I accumulate from bottles each day." Two control group participants stated that while they care about sustainable practices, traditional packaging did not affect their perspectives.

TABLE 3 Thematic Analysis of Qualitative Findings.

Theme	Key Findings	Supportive Quotes (Experimental Group)	Supportive Quotes (Control Group)
1) Consumer Engagement with AR	High interest, interactive appeal	"The AR made the packaging more exciting and informative."	"I prefer simple packaging, but the AR was interesting to explore."
2) Usability Challenges	Technical issues, scanning difficulties	"It was difficult to scan the AR feature in dim lighting."	"I couldn't access the AR, so it didn't impact my choice."
3) Impact on Sustainability	Increased awareness, eco-friendly choices	"I now realize how much plastic waste I generate daily."	"I already prioritize sustainability, AR didn't change my view."

5 DISCUSSION

The purpose of this study was to research whether and how AR-enhanced paper-based beverage packaging could impact consumer perception and purchase intention through a quasi-experimental mixed-method design. Integrating quantitative, qualitative, and observational data allowed conclusions to move beyond whether AR-enhanced packaging affected study participants. Instead of reiterating the statistically significant results of this study, this discussion explains how AR functions as an interactive communication design strategy that enhances consumer engagement, strengthens sustainability communication, and extends the communicative role of sustainable packaging. This discussion will be divided into four parts. First, how AR's interactivity played a role in heightened consumer perception and engagement. Next, how AR can act as another channel

of communication for sustainable packaging to deliver information about its environmental benefits in a more prominent, experiential way. Third, the design implications of this study for packaging design and interaction design. Finally, this paper will discuss its limitations and future research directions to help build stronger cases for AR's effectiveness in sustainable packaging.

5.1 AR and Consumer Perception

The results showed that consumers evaluated products with AR packaging more positively than products with traditional packaging. Instead of claiming differences between both groups, this research goes further to show how AR can improve consumer perceptions of packaging by allowing packaging to move beyond static information display to engagement and communication with consumers [34]. Participants were drawn into the packaging through digital content that was both novel and stimulating. This prompted them to explore more information about the product than participants who were given traditional packaging. These findings correspond with those seen in consumers' ratings of product attractiveness, credibility and intent to purchase. Qualitative results have helped to uncover why this may be. Comments made by participants about the AR experience were descriptive of it being fun, new and informative. This implies that the AR experience provoked participants' curiosity and connected with them on an emotional level. Not only did they have access to the same information provided by traditional packaging, but they could also interact at their own interest with information about sustainability, animations and learn new information. Learning by doing is known to have a positive effect on cognitive processing of information. Instead of reading the same material, consumers interacting with AR packaging are able to experience packaging while learning new information. It also allowed consumers to have fun while reading information about the product. Observations of participants showed that participants in the AR group spent more time interacting with the packaging and went back to interact with the AR experience multiple times. Therefore, AR can not only allow consumers to interact with their product but also leave a better impression by allowing them to learn more about their product.

5.2 AR as Interactive Sustainability Communication

The key finding of this research is that AR should be considered an interactive communication design strategy rather than simply a technical feature. AR can transform sustainable packaging from a static information vehicle to an interactive digital communication platform. Communicating sustainability throughpackaging is inherently challenging because products have limited space to describe things like a product's life cycle, recycling information, material selection, and other sustainability efforts [35]. Packaging with AR transports consumers to a dynamic digital environment where these issues can become more prominent, compelling, and easier to comprehend. This was evidenced through triangulation of the mixed-method results. Quantitatively, participants who interacted with the AR package had significantly higher package perception, preference, and sustainability cognition. Qualitatively, participants described the AR experience as informative, memorable, and emotionally connecting. Taken together, these results indicate that AR may influence consumers through three cognitive, emotional, and behavioral pathways. AR can improve consumers' understanding of information (cognitive), inspire emotions of curiosity and enjoyment (emotional), and encourage interaction (behavior) [36]. As such, AR represents an interactive communication design strategy that complements conventional packaging by expanding its capacity to communicate sustainability information in a more engaging and meaningful manner [37].

5.3 Design Implications

These considerations empower packaging designers and marketers to frame AR as a communicative enhancement for sustainable packaging, rather than a fleeting technological novelty. Firstly, Augmented Reality should not replace other important design elements such as color, font, visibility of the actual product, brand visibility and information hierarchy because packaging design still primarily serves consumer needs to identify products. Secondly, sustainability information delivered via AR should be simple, aesthetically pleasing and easy to comprehend. Interactive material should aim to educate consumers in ways that are useful such as what part of the packaging is recyclable, how it benefits the environment and how to dispose of it responsibly rather than just for entertainment purposes. Thirdly, interacting with AR should be convenient for users. Scanning QR-codes should work in all types of lighting, load quickly and AR apps should be compatible with both newer and older versions of smartphone technology [38]. This can be achieved by viewing AR as another channel of communication on top of regular packaging elements.

5.4 Limitations

Although the results provide valuable initial insights, further research with a larger sample size will allow the generalisation of the findings. Secondly, the participants in the study were limited to those living in Klang Valley who identified as Generation X and Generation Y consumers. Future research may want to expand the study to include consumers of other geographic locations and age groups. Thirdly, this study only tested a singular context: paper-based beverage packaging. Other product types and packaging forms may yield different results. Lastly, consumers experienced the AR packaging in a controlled environment over a short period. The difference was drawn between sustainable packaging that enabled AR and the control packaging. In other words, two aspects changed between the control and experiment group – the packaging (material and design) and the addition of AR. Future studies may consider having two different sets of paper-based packaging to fully understand the added value of AR on consumer's sustainable purchasing behavior.

6 CONCLUSION

Results from the quantitative component revealed a significant difference in perceived consumer perceptions and purchase intention scores between the AR-enhanced paper packaging and the control group (traditional packaging). In contrast, results from the qualitative component provided further explanation for this difference; respondents reported that they found the AR experience interactive, informative and engaging, whilst observation revealed that respondents spent longer exploring the information made available through AR [39]. Consequently, the study contributes to sustainable communication and packaging design by demonstrating that AR acts as an interactive strategy, enhancing the informational scope of sustainable packaging beyond static printed content. Rather than merely influencing consumer responses, AR enables packaging to become a more engaging and informative communication platform for conveying sustainability messages. Consideration must be given to ensure that AR experiences are accessible to all consumers, work effectively across devices and are easy to use with quick loading performance. Future studies should employ larger samples, observe consumer behavior across multiple products and utilizes longitudinal studies to measure purchases instead of purchase intentions [40].

Acknowledgements

This project supported by Taylor's University through its Taylor's Research Excellence Scholarships (Scheme D).

REFERENCES

[1] Liang Y, Tan Q, Song Q, Li J. An analysis of the plastic waste trade and management in Asia. *Waste Management*. 2021;119:242-253. https://doi.org/10.1016/j.wasman.2020.09.049

[2] Chen HL, Nath TK, Chong S, Foo V, Gibbins C, Lechner AM. The plastic waste problem in Malaysia: management, recycling and disposal of local and global plastic waste. *SN Appl Sci. Springer Nature*. 2021;3(4). https://doi.org/10.1007/s42452-021-04234-y

[3] Boz Z, Korhonen V, Sand CK. Consumer considerations for the implementation of sustainable packaging: A review. *Sustainability (Switzerland)*. 2020;12(6). https://doi.org/10.3390/su12062192

[4] Cascini G, O'Hare J, Dekoninck E, et al. Exploring the use of AR technology for co-creative product and packaging design. *Comput Ind*. 2020;123. https://doi.org/10.1016/j.compind.2020.103308

[5] Voicu MC, Sîrghi N, Toth DMM. Consumers' Experience and Satisfaction Using Augmented Reality Apps in E-Shopping: New Empirical Evidence. *Applied Sciences (Switzerland)*. 2023;13(17). https://doi.org/10.3390/app13179596

[6] Papakostas C, Troussas C, Krouska A, Sgouropoulou C. Measuring user experience, usability and interactivity of a personalized mobile augmented reality training system. *Sensors*. 2021;21(11). https://doi.org/10.3390/s21113888

[7] Cheng KM, Tan JY, Wong SY, Koo AC, Sharji EA. A Review of Future Household Waste Management for Sustainable Environment in Malaysian Cities. *Sustainability (Switzerland)*. 2022;14(11).https://doi.org/10.3390/su14116517

[8] Mousa N, Galiwango E, Haris S, Al-marzouqi AH, Abu-jdayil B, Caires YL. A New Green Composite Based on Plasticized Polylactic Acid Mixed with Date Palm Waste for Single-Use Plastics Applications. *Polymers (Basel)*. 2022;14(3). https://doi.org/10.3390/polym14030574

[9] Perera KY, Jaiswal AK, Jaiswal S. Biopolymer-Based Sustainable Food Packaging Materials: Challenges, Solutions, and

Applications. *Foods. MDPI.* 2023;12(12). https://doi.org/10.3390/foods12122422

[10] Yu W, Hassan A, Adhikariparajuli M. How Did Amazon Achieve CSR and Some Sustainable Development Goals (SDGs)—Climate Change, Circular Economy, Water Resources and Employee Rights during COVID-19? *Journal of Risk and Financial Management.* 2022;15(8). https://doi.org/10.3390/jrfm15080364

[11] Thapliyal D, Karale M, Diwan V, Kumra S, Arya RK, Verros GD. Current Status of Sustainable Food Packaging Regulations: Global Perspective. *Sustainability (Switzerland).* 2024;16(13):1-26. https://doi.org/10.3390/su16135554

[12] Gumienna M, Górna B. Antimicrobial food packaging with biodegradable polymers and bacteriocins. *Molecules.* 2021;26(12). https://doi.org/10.3390/molecules26123735

[13] Sousa MMM de, Carvalho FM, Pereira RGFA. Colour and shape of design elements of the packaging labels influence consumer expectations and hedonic judgments of specialty coffee. *Food Qual Prefer.* 2020;83. https://doi.org/10.1016/j.foodqual.2020.103902

[14] Grandi F, Khamaisi RK, Peruzzini M, Raffaeli R, Pellicciari M. A reference framework to combine model-based design and AR to improve social sustainability. *Sustainability (Switzerland).* 2021;13(4):1-16. https://doi.org/10.3390/su13042031

[15] Accardi S, Campo C, Bilucaglia M, Zito M, Caccamo M, Russo V. Static vs. Immersive: A Neuromarketing Exploratory Study of Augmented Reality on Packaging Labels. *Behavioral Sciences.* 2025;15(9). https://doi.org/10.3390/bs15091241

[16] Davidescu MA, Pânzaru C, Mădescu BM, et al. Advances and Challenges in Smart Packaging Technologies for the Food Industry: Trends, Applications, and Sustainability Considerations. *Foods. Multidisciplinary Digital Publishing Institute (MDPI).* 2025;14(24). https://doi.org/10.3390/foods14244347

[17] Han DID, Abreu e Silva SG, Schröder K, Melissen F, Haggis-Burridge M. Designing Immersive Sustainable Food Experiences in Augmented Reality: A Consumer Participatory Co-Creation Approach. *Foods.* 2022;11(22). https://doi.org/10.3390/foods11223646

[18] Wijekoon R, Sabri MF. Determinants that influence green product purchase intention and behavior: A literature review and guiding framework. *Sustainability (Switzerland).* 2021;13(11):1-40. https://doi.org/10.3390/su13116219

[19] Creswell JW, Hirose M. Mixed methods and survey research in family medicine and community health. *Fam Med Community Health.* 2019;7(2):1-6. https://doi.org/10.1136/fmch-2018-000086

[20] Campbell S, Greenwood M, Prior S, et al. Purposive sampling: complex or simple? Research case examples. *Journal of Research in Nursing.* 2020;25(8):652-661. https://doi.org/10.1177/1744987120927206

[21] Abdul S, Bukhari R, Ali M. Sample Size Determination Using Krejcie and Morgan Table Strategic Management View project. https://doi.org/10.13140/RG.2.2.11445.19687

[22] Chirico A, Avellone M, Palombi T, et al. Exploring the Psychological Nexus of Virtual and Augmented Reality on Physical Activity in Older Adults: A Rapid Review. *Behavioral Sciences. Multidisciplinary Digital Publishing Institute (MDPI).* 2024;14(1). https://doi.org/10.3390/bs14010031

[23] Dawadi S, Shrestha S, Giri RA. Mixed-Methods Research: A Discussion on its Types, Challenges, and Criticisms. *Journal of Practical Studies in Education.* 2021;2(2):25-36. https://doi.org/10.46809/jpse.v2i2.20

[24] Karadavut Z, Çimen O. THE EFFECT OF AUGMENTED REALITY APPLICATIONS ON THE ACADEMIC SUCCESS OF 11TH GRADE STUDENTS IN THE CIRCULATORY SYSTEM. *European Journal of Education Studies.* 2021;8(12). https://doi.org/10.46827/ejes.v8i12.4030

[25] Lin YH. Determinants of Green Purchase Intention: The Roles of Green Enjoyment, Green Intrinsic Motivation, and Green Brand Love. *Sustainability (Switzerland).* 2023;15(1). https://doi.org/10.3390/su15010132

[26] Głuszek E. Use of the e-Delphi method to validate the corporate reputation management maturity model (CR3M). *Sustainability (Switzerland).* 2021;13(21). https://doi.org/10.3390/su132112019

[27] Wikarsa L, La D. Using Technology Acceptance Model to Evaluate the Utilization of Kolintang Instruments Application. *Article in Journal Pekommas*. Published online 2021. https://doi.org/10.30818/jpkm.2021.2060104

[28] Salimi NT, Ezbarami ZT, Tabari-Khomeiran R, Roushan ZA, Hashemian H, Astaneh HK. Comparing the effects of mobile-based education and booklet-based education on Iranian mothers' perception on antibiotics: a quasi-experimental study. *J Pediatr Nurs*. 2021;61:122-129. https://doi.org/10.1016/j.pedn.2021.04.034

[29] Khan NU, Wei H, Yue G, Nazir N, Zainol NR. Exploring themes of sustainable practices in manufacturing industry: Using thematic networks approach. *Sustainability (Switzerland)*. 2021;13(18). https://doi.org/10.3390/su131810288

[30] Syed TA, Siddiqui MS, Abdullah HB, et al. In-Depth Review of Augmented Reality: Tracking Technologies, Development Tools, AR Displays, Collaborative AR, and Security Concerns. *Sensors. MDPI*. 2023;23(1). https://doi.org/10.3390/s23010146

[31] Şimşek EE. The Use of Augmented Reality-Supported Activities in Environmental Education for Early Childhood: A Quasi-Experimental Study. *Sustainability (Switzerland)*. 2024;16(23). https://doi.org/10.3390/su162310374

[32] Guo J, Pan Y. What Factors Impact Visitors' Intentions to Use Location-Based AR Games? An Empirical Study from Chinese Cultural Heritage Sites. *Sustainability (Switzerland)*. 2023;15(19). https://doi.org/10.3390/su151914328

[33] Gu C, Huang T, Wei W, et al. The Effect of Using Augmented Reality Technology in Takeaway Food Packaging to Improve Young Consumers' Negative Evaluations. *Agriculture (Switzerland)*. 2023;13(2). https://doi.org/10.3390/agriculture13020335

[34] Styliaras GD. Augmented Reality in Food Promotion and Analysis: Review and Potentials. *Digital*. 2021;1(4):216-240. https://doi.org/10.3390/digital1040016

[35] Santi R, Garrone P, Iannantuoni M, Del Curto B. Sustainable Food Packaging: An Integrative Framework. *Sustainability (Switzerland)*. 2022;14(13). https://doi.org/10.3390/su14138045

[36] AL Hilal NSH. The Impact of the Use of Augmented Reality on Online Purchasing Behavior Sustainability: The Saudi Consumer as a Model. *Sustainability (Switzerland)* . 2023;15(6). https://doi.org/10.3390/su15065448

[37] Acerbi F, Sassanelli C, Terzi S, Taisch M. A systematic literature review on data and information required for circular manufacturing strategies adoption. *Sustainability (Switzerland)*. 2021;13(4):1-27. https://doi.org/10.3390/su13042047

[38] Wan F, Teng J, Feng L. Exploring User Attitudes and Behavioral Intentions towards Augmented Reality Automotive Assistants: A Mixed-Methods Approach. *World Electric Vehicle Journal*. 2024;15(6). https://doi.org/10.3390/wevj15060258

[39] Irwanto I, Dianawati R, Lukman IR. Trends of Augmented Reality Applications in Science Education: A Systematic Review from 2007 to 2022. *International Journal of Emerging Technologies in Learning*. 2022;17(13):157-175. https://doi.org/10.3991/ijet.v17i13.30587

[40] Kim N, Lee K. Environmental Consciousness, Purchase Intention, and Actual Purchase Behavior of Eco-Friendly Products: The Moderating Impact of Situational Context. *Int J Environ Res Public Health*. 2023;20(7). https://doi.org/10.3390/ijerph20075312