Introduction and Literature Review

In recent years, agricultural sustainability efforts and initiatives have been at the forefront of conversations within the livestock industry (Tikhonovich & Provorov, 2011; Wang et al., 2009). However, the concept of sustainability is complex, as it focuses on three distinct pillars: environmental, economic, and social (USDA, 2022). According to the USDA (2022), sustainability efforts should seek to "balance the goals of satisfying human needs; enhancing environmental quality, the resource base, and ecosystem services; sustaining the economic viability of agriculture; and enhancing the quality of life for farmers, ranchers, forest managers, workers and society as a whole" (para. 3). Following the USDA, many agricultural organizations have shared commitments to attaining sustainable goals and publicizing these efforts with members of the public to inform them of their efforts (e.g., Cotton Inc, 2023; NCBA, 2023). However, the concept of agricultural sustainability, specifically sustainable beef production, is not well established, and much misinformation frames this conversation (Griekspoor, 2019). Because of the lack of knowledge and influx of misinformation, the public tends to have little understanding of sustainable beef production practices (dos Santos Freitas et al., 2017). Therefore, there is a need for agricultural communicators to educate and inform members of the public on sustainable agricultural practices.

There are many methods and types of media agricultural communicators have previously used to disseminate information to audiences; however, the incorporation and use of visual communication techniques is increasing (Waller al., 2020). In an era of information overload (Brumberger, 2007), visuals are an ideal communication strategy to help narrow this information gap between agriculturalists and the public (Whitaker, 2020). Visual communication has been used to effectively communicate complex agricultural information, concepts, or topics (Gibson et al., 2018) because visuals processed significantly faster than words (Semetko & Scammell, 2012).

One way agricultural communicators can educate the public on sustainable agricultural practices is through the visual communication technique of the infographic, which has been described as a powerful type of visual communications tool (Dunlap & Lowenthal, 2016; Smiciklas, 2012). The term "infographic" refers to visualizing complex data or ideas for an audience to easily understand (Adi & Ariesta, 2019). Infographics can be used to share unique, novel, and complex information, and have been found to attract viewer attention (Smiciklas, 2012). However, communicators must create the most influential infographic to inform the public about topics, such as agricultural sustainability practices.

Members of the public searching for information related to agricultural sustainability may grasp and retain information easier when viewing infographics, leading to improved comprehension, enhanced critical thinking, and improved recall of information (Adi & Ariesta, 2019; Smiciklas, 2012). Therefore, infographics could lead to increased agricultural literacy about sustainable practices. Infographics may be one communication tactic that helps receivers achieve more in-depth processing by using and combining text and data visualizations to communicate information (Smiciklas, 2012).

Within the infographic, communicators use data visualizations, defined as the images, signs, maps, graphs, and charts that display quantitative data to deliver information quickly in a visual format (Naparin & Saad, 2017; Yang, 2017). Siricharoen and Siricharoen's (2015) research found the most successful types of data visualizations to express quantitative information were bar graphs, pie charts, pictographs, flowcharts, scatterplots, and line graphs.

Overall, these data visualizations enhance the comprehension of quantitative data through patterns that assist in viewing and holding the viewer's attention (Lipkus & Hollands, 1999). As infographics are becoming a more commonly used visual communication tool across industries such as agricultural sustainability, agricultural communicators should use and design them as effectively as possible to deliver quantitative information in a competitive market for consumer attention.

Within agricultural communications, several researchers have explored how infographics impact what individuals recall and recognize. Previous literature has provided a solid foundation of the positive influence infographics have when communicating complex information because the human brain recognizes and processes the information more effectively (Hassan, 2016). Afify (2018), Lamm et al. (2020), and Holt et al. (2020) found infographics facilitate better viewer retention and recall of information compared to ordinary texts resulting in extended and lasting learning. However, Burnett et al. (2019) and Lamm et al. (2020) claimed there are limited studies on infographics in agricultural communications. Additionally, we posit that there is little research within agricultural communications focused on the role of the design and the types of data visualizations used in infographics and how it influences recall and information recognition.

Outside of the agricultural communications profession, several research studies have studied the role of design and the types of data visualizations used in infographics. To make the largest effect in information delivery, agricultural communicators must optimize infographic design infographics to deliver information in a competitive market. A technique to alter the design of the infographic is to ensure the data visualization, or the graphical presentation of the data, is educational, understandable, and effective to the audience (Siricharoen & Siricharoen, 2015). Scholars have previously explored how types of data visualizations have impacted the effectiveness of the visual communication techniques. For example, studies have found bar graphs, pie charts, and pictographs to be the most used and compelling types of data visualizations to be utilized in the infographics (Brewer et al., 2012; Houts et al., 1997; Linden et al., 2014; Sullivan et al., 2016; Umanath & Scamell, 1988).

Bar Graphs

A simple, yet effective, data visualization is a bar graph that shows complex comparisons (Umanath & Scamell, 1988). The heights of the bars in the graph are proportional to the values they represent (Hofmann et al., 2019). Bar graphs are a standard chart, intuitive, and easy to understand when visualizing large volumes of data (Keim et al., 2002) and are ultimately the most favorable for increasing recall of information (Umanath & Scamell, 1988). Umanath and Scmell (1988) looked at the effects of bar graphs versus tables on recall performance and found bar graphs to be a more effective display. Brewer et al. (2012) found readers required less viewing time when bar graphs were used. Sullivan et al. (2016) evaluated the visual aids often used to present quantitative data and found that bar graphs and tables were the most successful overall.

Pie Charts

Pie charts are circular statistical graphs that are divided and illustrate a numerical proportion of a whole value (Bozoki, 2020). Linden et al. (2014) suggested proportions are more effectively processed when presented in the form of a pie chart. Their research indicated that pie charts were moderately more effective at recalling information. Similarly, Scalia et al. (2019) analyzed data visualizations in the formats of pictographs, pie charts, bar graphs, and line charts. Their participants preferred pie charts to illustrate the time-dependent risk of stroke and death. Scalia et al. (2019) found their participants were overwhelmed and had difficulty interpreting the information when presented in a pictograph format.

Pictographs

Pictographs are pictures or icons used to represent data or ideas, assisting in increasing information recall (Houts et al., 1997). Communicators can use pictographs for simple comparisons (Umanath & Scamell, 1988). Pictographs increase the understanding of quantitative information (Sullivan et al., 2016). Hess et al. (2011) conducted three studies to investigate how pictographs communicate medical information. Hess's (2011) research found pictographs were helpful for persons with higher and lower numeracy skills; however, these groups process the visualization differently. Those with higher numeracy relied more on the numerical information, whereas persons with lower numeracy seemed to be confused when guided toward these numbers.

Although prior research outside of agriculture has assessed the design or data visualization technique used in infographics, there is a lack of research on understanding the influence of different types of data visualizations used in agricultural infographics and their effect on viewers' ability to recall information about agricultural science. This type of research is needed to better evaluate the influences data visualizations have on helping individuals learn more about agricultural topics, such as agricultural sustainability, and what type of data visualization helps individuals to retain information (Waller et al., 2020).

Theoretical Framework

For agricultural communicators to communicate most effectively to consumers about topics such as agricultural sustainability, it is essential to understand what type of data visualizations leads to increased recall and the retention of information to create effectively designed infographics. Understanding the most effective type of data visualization will allow communicators to better educate consumers, decreasing the misunderstanding and misinformation surrounding the agricultural industry and its practices, such as sustainability practices.

Scholars have suggested recall, or the mental process of retrieving information from the past, as one way to understand what someone has comprehended when exposed to new information (Lang, 2000, 2009). Within agricultural communications literature, a variety of information processing theories have been utilized to help provide patterns and frameworks detailing the thought process when exposed to information, such as the Elaboration Likelihood Model (ELM), the Heuristic Systematic Processing Model (HSM), and The Limited Capacity Model of Motivated Mediated Message Processing (LC4MP). Although the ELM and the HSM provide frameworks for understanding how deeply an individual processes information via the central/systematic or the heuristic/peripheral route, the LC4MP provides a framework for understanding how individuals absorb information from their surroundings and are able to recognize, regurgitate, and/or recall this information and has been utilized in prior agricultural communication studies regarding recall (Fischer, 2022; Waller et al., 2020). For example, Waller et al. (2020) used the LC4MP to examine how participants' free and cued recall varied based on infographic vs. narrative about genetic modification. Additionally, Fischer et al. (2022) used the LC4MP to examine what people were able to recall when they encountered at-risk weather information. For this specific study, the LC4MP provides insight into human information processing, information recognition, and recall, and it guided this study's development.

The seminal theoretical piece developed by Lang in 2009 explained LC4MP as a theoretical model that describes the dynamic nature of human information processing and the psychological consumption of media. It provides a framework to track the interactions occurring between the message receiver after they have been exposed to information. The LC4MP is based upon the idea that humans have a limited capacity when processing information (Fisher & Weber, 2020; Lang, 2009), meaning individuals prioritize certain information when processing a message due to their limited capacity (Fisher & Weber, 2020). When processing information, humans process information in three stages known as *encoding*, *storage*, and *retrieval* (Lang, 2009).

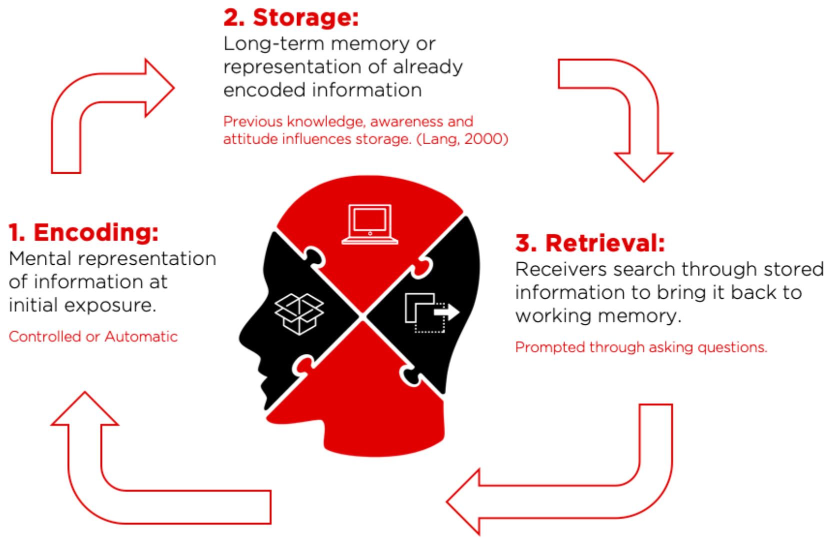
Encoding, the first subprocess of the LC4MP, is the initial stage of perceiving and learning information, and it occurs when the individual creates a mental representation of viewed information when they are initially exposed to a message (Lang, 2000, 2006). After the individual is exposed to information, they will subconsciously process what aspects of the information to encode from their information environment (Lang, 2000, 2006). Aspects of information are encoded based on message design features (e.g., contrasting colors, text elements, graphic elements, etc.) and/or individual features (e.g., information that is in line with prior viewing habits and motivations, or information that aligns with the viewers' prior beliefs, knowledge, and experiences; Lang, 2000, 2006, Fischer et al., 2023).

The second subprocess of the LC4MP is *storage*, which refers to the long-term memory of the encoded information and how it is kept in working memory over time (Lang, 2009). In this stage, individuals attempt to make sense of new information, and they associate the new information with prior knowledge or previously stored information. The storage phase helps individuals to create a repository of information that will be later retrieved, in the third phase (retrieval), to make judgments and evaluations (Lang, 2000).

In the final subprocess, *retrieval*, receivers search through stored information to bring it back to their working memory to make judgments and evaluations (Lang, 2000; Lang et al., 2012). Information can be retrieved through prompting or asking questions following message processing via free or cued recall prompts (Lang, 2009). Individuals constantly recover and process old information to contextualize and understand incoming information (Lang, 2009). It is also important to note that individuals can engage in all three of these processes simultaneously, as information processing can happen differently depending on the viewer and the content (Lang, 2000). Figure 1 illustrates the LC4MP method and viewers' three subprocesses when viewing content.

Figure 1

LC4MP Subprocesses Flow, Adapted from Lang (2000, 2006, 2009).



The LC4MP has been used to study recall and information recognition in a variety of studies. Within agricultural communications research, Waller et al. (2020) used the LC4MP to study the effects of narrative versus infographic information on college students' ability to recognize information. Their findings indicated that there were no statistically significant differences found between infographic versus narrative information formats, contradicting their literature review suggesting infographics outperformed purely textual information (Comello et al., 2016; Yildrim, 2016).

Despite this finding, our review of the literature indicates different data visualization techniques may lead to differences in recall and information recognition. Additionally, scholars have indicated building and designing effective messages and crafting design elements, like data visualizations, that stand out and can be interpreted is critical to ensure the important parts of the message are encoded, stored, and later retrieved for individuals to be informed and make future decisions (Fisher & Weber, 2018; Fischer et al., 2022; Lang, 2000, 2009; Lang et al., 2012). Effective graphic design techniques are particularly important within the encoding process (Lang, 2000, 2006) as items that are visually salient have the tendency to be viewed more frequently and later remembered (Fine & Minnery, 2009). Specifically, the LC4MP posits different message elements will be collected to be processed; however, due to the fact that humans have a limited capacity, individuals typically confront more information than they can store. Consequently, only pieces that stand out, or are visually salient, to the receiver will be processed into working memory (Lang, 2000; Thomas & Irwin, 2006). One approach to understanding what components of a message are encoded is to focus on a message-centered approach, where researchers uncover what elements of a design are visually salient.

Visual salience has typically been studied within the field of advertising to understand how attention is directed toward print advertisements (Lohse, 1997; Pieters & Wedel, 2004). Visual salience, within this realm, has been described as message features that 'pop out' from their surroundings, can be detected from their surroundings, and receive visual attention (Gong, 2016; Pieters & Wedel, 2007; Yantis, 1993). Much research has shown visual saliency drives attention (i.e., Gong, 2016; Lohse, 1997; Pieters & Wedel, 2004). In line with the LC4MP, if visual elements are given attention, there is a higher probability that they will be encoded and later stored within the working memory. Within the current study, we seek to lay preliminary groundwork on understanding how message features within data visualizations are processed by the receiver.

Purpose and Research Objectives

This study specifically explored the types of data visualizations used in agricultural infographics about beef sustainability practices and their effects on recall and information recognition. The purpose of this study was to determine the effect various types of data visualizations used in infographics about beef sustainability have on college students' information recognition and ability to recall information and design elements presented in the infographic. The following objectives were used to guide this study:

RO1: Describe the participants' ability to recall design and information elements as well as recognize information from the infographic.

RO2: Determine if the participants' recall (free & cued) of the design elements and information expressed in an infographic varied by the type of data visualizations used.

RO3: Determine if the participants' information recognition varied by the type of data visualizations used.

Methods

The researchers developed and conducted an experimental research study to compare how the participants recall and information recognition differed after being exposed to an infographic (Dimitrov & Rumrill, 2003; Wimmer & Dominick, 2003). A survey instrument was developed with an embedded experiment and distributed via Qualtrics. The current study used a pre-test to measure the participants' demographic information. Next, the participants were exposed to one of three infographics that used either bar charts, pie charts, or pictographs. Finally, the post-test measured the participants free and cued recall of information, free and cued recall of design, and their information recognition after being exposed to one of three infographics. Through this design, the researchers used three comparison groups to study the effects of the different types of data visualizations (i.e., bar charts, pie charts, and pictographs) on participants recall and information recognition. Researchers received approval to conduct this study from Texas Tech University Human Research Protection Program prior to data collection. To ensure validity and reliability, the researchers had an expert panel who specialized in beef sustainability, recall, and experimental design review the instrument. Panel members included agricultural communications faculty, media and communication faculty, and an industry expert. Additionally, a pilot test with graduate students in the Department of Agricultural Education and Communications was conducted to ensure instrument clarity. Reliability techniques are reported within the independent and dependent variables section below. This data is part of a larger study, and the data were analyzed independently from the other variables.

Participants

The participants for this study consisted of undergraduate students at Texas Tech University. Since the purpose of this study was to examine the effects of the data visualization type on participant recall and information recognition, a convenience sample of college students was found to be appropriate, as we did not seek to provide inferences to a population. Thorson et al. (2012) and Wimmer and Dominick (2014) confirmed that experimental design methods using convenience samples may help researchers to understand and make inferences to the relationships among and between the variables in the experiment, such as data visualization type and recall, and inferences cannot be applied to populations as a whole and we discuss this as a limitation in our conclusions. For example, Thorson et al (2012) states:

> Experimental researchers typically acquire convenience samples (like second graders from several school districts in town, college students enrolled in large communication classes, or adults who agree to participate in an experiment for a chance to win a digital music player). These individuals are then randomly assigned to the conditions in the experiment. Because there is no random sampling of participants, inferences cannot be applied to the likelihood that values found in the experiment representative of values that would be found in the population as a whole. Instead, logical inferences are made about the multivariate relationships among the variables in the experiment. The "population" in this case is all possible samples one could randomly draw from the group of individuals in the experiment. (p. 117)

Additionally, many current undergraduate students are categorized as Generation Z (those born after 1996). Members of Gen Z are known for being "digital natives, who have little or no memory of the world as it existed before smartphones" (Parker & Igielnik, 2020, para. 4) and prefer learning information through passive and visual techniques (Shorey et al., 2021). Due to this combination, undergraduate students have been known to consume many visuals, including online infographics, to learn about topics. Therefore, we found this population to be a key target for our research.

Our convenience sample consisted of 197 participant responses collected from SONA, an undergraduate student research recruitment pool, and 273 participant responses from the university wide email system, with 470 total participants who completed the questionnaire. Of those, 232 responses were removed due to missing information, responding too quickly, or not quickly enough. After removing incomplete or inadequate responses, 238 responses were kept within the study and were analyzed.

Participant demographics were gathered and consisted of gender, age, ethnicity, academic classification, and academic college. Of the 238 complete responses, researchers found most participants identified as White or Caucasian (n = 164, 68.9%) and female (n = 182, 76.5%). The mean birth year of the participants was 1999.94 (SD = 6.22), with the oldest being born in 1970 and the youngest being born in 2005. Academically, most participants were classified as first-year students having earned 0-29 hours of course credit) (n = 70, 29.4%) and were from the College of Human Sciences (n = 98, 41.7%). Approximately half of the participants (n = 127, 53%) identified their hometown as an urbanized area, consuming beef anywhere from 1-4 days per week 186 (78.3%), and had no avoidance of beef for health, religious or any other reasons (n = 210, 88.2%).

Table 1

Gender, Ethnicity, and Generation of Participants (N = 238)

Characteristic	Frequency *(n)*	Frequency Percent *(%)*
Gender		
Female	182	76.5
Male	52	21.8
Ethnicity		
White or Caucasian	164	68.9
Hispanic or Latinx	39	16.4
Black or African American	13	5.5
Asian/Asian-American	9	3.8
Choose Not to Answer	5	2.1
Other	4	1.7
Native American/Alaska Native	2	.8
Native Hawaiian/Pacific Islander	2	.8
Academic Classification		
First Year (0 – 29 hours)	70	29.4
Sophomore (20 – 59 hours)	67	28.2
Senior (90 + hours)	52	21.8
Junior (60 – 89 hours)	49	20.6
Academic College		
College of Human Sciences	98	41.7
College of Arts and Sciences	44	18.5
College of Media and Communication	35	14.7
Davis College of Agricultural Sciences & Natural Resources	32	13.4
College of Engineering	16	6.7
Rawls College of Business	10	4.2
College of Education	3	1.3
Honors College	3	1.3
College of Architecture	2	.8
Visual and Performing Arts	2	.8
Urban-rural Classification		
Urbanized Area (50,000 or more)	127	53.4
Urban Cluster (2,500 to 50,000)	77	32.4
Rural (less than 2,500)	33	13.9
Beef Consumption		
1 – 2 days per week	93	39.1
3 – 4 days per week	93	39.1
5 – 6 days per week	24	10.1
Never	19	8.0
Everyday	8	3.4
No Response	1	.4
Avoidance of Beef		
No	210	88.2

Yes	27	11.3
No Response	1	.4

Independent Variables

The independent variable for the study was the type of data visualization used in the infographic stimuli.

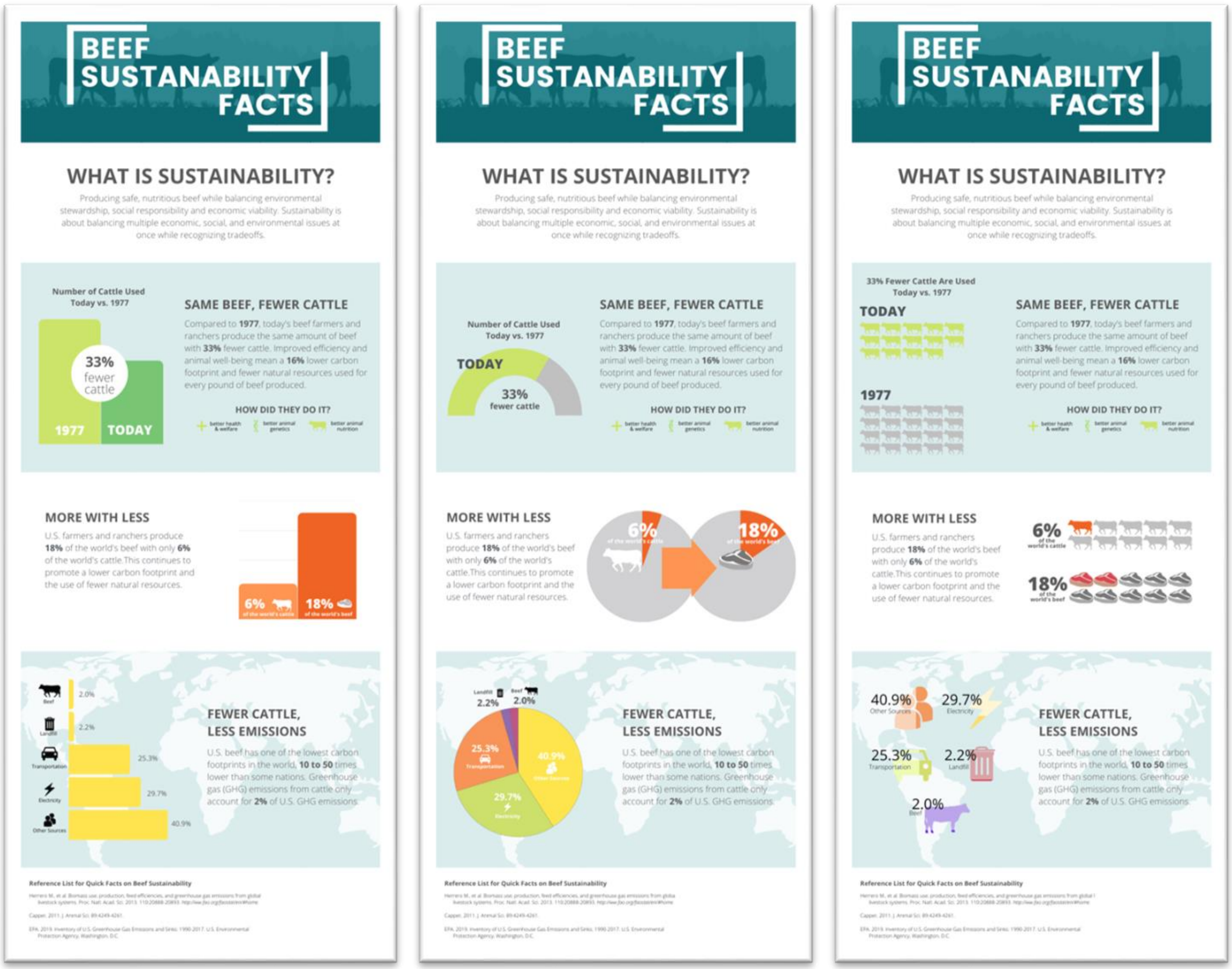
Stimuli and Data Visualization Type

A panel of experts agreed on beef sustainability as the context of our study and thus the focus of the infographic to gauge information recognition and recall of information, as it is a topic of much discussion in the agricultural sector. The data and information used in the infographics created for this study were based upon the 'Beef Sustainability Facts' infographic found in a New York Beef Council publication designed by the National Cattleman's Beef Association (NY Beef Council, n.d.).

Participants were randomly assigned one of three infographics to view. Each infographic used the same three main data points regarding beef sustainability and the carbon footprint of the beef industry. However, the stimuli were manipulated based on the type of data visualization: bar chart, pictograph, and pie chart (Figure 2). These data visualizations were chosen because researchers found them to be the most used and compelling when used in infographics (Brewer et al., 2012; Houts et al., 1997; Linden et al., 2014; Sullivan et al., 2016; Umanath & Scamell, 1988).

Figure 2

Beef Sustainability Infographics used in the Study (Left, Bar Charts; Center, Pie Charts; Right, Pictograph)



Dependent Variables

The dependent variables in this study were participants' recall (both free and cued) of design and information and their post-test information recognition. The dependent variable constructs were collected after the participants responded to the pre-test questions and after the participants were exposed to the stimuli. To ensure participants could not go back to the stimuli when answering the questions, we ensured that there was not a back button on the Qualtrics platform.

Free Recall

Researchers first used free recall to measure the retrieval process of information about beef sustainability. In prior studies, free recall has been measured by asking the participants an open-ended question about what they remembered from the stimuli that they viewed (Aue et al., 2016). Lang (2000) explained the retrieval process could be observed by how well participants could recall information from a stimulus with no cues to aid them. Free recall was measured in two categories: 1) design elements and 2) information/data. Two questions were used to analyze the free recall of participants – one question regarding design elements and the other regarding information/data. Both questions were open-ended, leaving an opportunity for multiple text-based answers. Answers were measured as qualitative data, as key message statements were identified to account for participant answers with slight variances but representing the same ideas (1 = *Mentioned*, 2 = *Not Mentioned*).

Free Recall of Design Elements. Following the presentation of one of the stimuli, the participants were asked "Please list any design elements (i.e., lines, shapes, colors, etc.) or data visualization elements (i.e., charts, graphs, images, etc.) in the infographic that you just viewed."

Free Recall of Information. Next, the participants were asked "Please list any content, information, data, themes, ideas, etc. you can recall from the infographic you just viewed."

Cued Recall

After the free recall questions, the researchers used cued recall to measure the storage process impacting the participants' memory when given a cue to assist in retrieval (Aue et al., 2016). With cued recall, participants are given a cue and must retrieve the correct memory based on the given cue (Aue et al., 2016). To test participants' cued recall of the data and design in the infographic, they were randomly provided the participants were given 10 questions related to the design elements (3) and information (7) derived from the infographic they viewed. Cued recall of design answers was analyzed similarly to free recall (1 = *Mentioned*, 2 = *Not Mentioned*). Cued recall of information was coded as being correct or incorrect (1 = *Correct*, 0 = *Incorrect*).

Cued Recall of Design Elements. The cued recall questions were based on the design elements used in the infographic (i.e., line segments, shapes, colors, charts, graphs, etc.). These questions included: 1) What types of charts or graphs did you see in the infographic, 2) What colors did you notice throughout the infographic, 3) What icons, line elements, or images did you notice?

Cued Recall of Information. Seven cued recall questions were provided based on the information and data (i.e., statistics, data, facts, etc.) presented in the infographic. These questions included: 1) What was described as having the lowest greenhouse gas emissions in the U.S., 2) To the best of your ability, list the topics from highest to lowest according to the amount of greenhouse gas emissions, 3) Compared to 1977, _____% fewer cattle are used to produce the same amount of beef, 4) U.S. farmers and ranchers produce _____% of the world's beef with only _____% of the world's cattle, 5) The greenhouse gas emissions from beef cattle only represents _____% of emissions in the U.S., 6) U.S. beef has one of the lowest carbon footprints in the world, 10 -___ times lower than some nations, and 7) How were farmers and ranchers able to reduce the number of cattle needed to produce the same amount of beef.

Information Recognition

Finally, the researchers also tested information recognition to measure the retrieval process of participants. Lang (2000) explained this is a sensitive measurement of memory, and cues help retrieve the viewed information. Following exposure to the stimuli, participants all received the prior knowledge questions to assess their recognition of the presented information and if it varied based on the type of data visualization they viewed in their randomly assigned infographic. The questions included the following: 1) Compared to 1977, today's beef farmers and ranchers produce the same amount of beef with 53% fewer cattle, 2) Better health, genetics, and nutrition are three reasons the U.S. needs fewer cattle to produce the same amount of beef, 3) U.S. beef has one of the lowest carbon footprints in the world, 4) The beef industry accounts for 6% of U.S. greenhouse gas emissions, 5) When comparing the U.S. beef emissions, they are 10-50 times lower than other nations, 6) 'Other Sources' was labeled as having 76% of greenhouse gas emissions, 7) The U.S. produces 18% of the world's beef with only 6% of the world's cattle, 8) Sustainability is balancing environmental stewardship, social responsibility and economic viability, and 9) U.S. farmers can reduce the number of cattle needed through better health and welfare, genetics, and nutrition. Participants information recognition was recorded as the total number of correct answers of the true/false questions, where 1 = *Correct* and 0 = *Incorrect*. Reliability was calculated using the KR-20 reliability coefficient, and it was found to have fair reliability with a KR-20 score of .67 (Mohamad et al., 2015; Tan, 2006).

Data Analysis

Data were collected in Qualtrics. The free recall of design elements and information/data questions that appeared after participants were exposed to stimuli required a deductive analysis approach. Following the technique Waller et al. (2020) implemented, the researchers identified key message statements from the stimuli (i.e., fewer cattle are needed to produce the same beef yield; U.S. beef has the smallest footprint). After identifying key statements, the researchers determined how many of those statements were presented and correct (1) or absent (0) in each response via a content analysis technique. This technique is helpful when looking for commonality among participant answers that have slight variances but represent the same ideas and provided a total count for free recall. The responses for cued recall and information recognition were scored as correct (1) or incorrect (0), and the resulting percentage correct was used to determine how much participants could correctly recall information or design elements from the stimulus shown. To ensure reliability, two coders independently analyzed the key message statements. ReCal 2.0 was used to ensure all variables reached the acceptable threshold of Krippendorff's alpha of .8 or higher.

After the deductive analysis, the frequency data were exported to SPSS Version 27. Descriptive were used to provide means, standard deviations, frequencies, and percentages of the data. A series of one-way ANOVAs were employed to further address the research objectives in providing comparisons between the type of data visualizations used in the infographic.

Results

RO1: Describe the participants' ability to recall design and information elements as well as recognize information from the infographic.

After exposure to the infographics, the participants were asked a series of questions to gather insight on what they could recall about the design elements and the information and what information they could recognize from the infographic.

Recall of Design Elements. To understand what participants could freely recall regarding the design elements of the infographic, the participants were asked to list any design elements they could recall from the infographic. The opportunity for multiple text answers required this question to be treated like qualitative data. The participants indicated they could freely recall elements such as graphs/charts, pie charts, pictographs, numbers and percentages, words/fonts, colors, and icons. To assign a numerical value, the researchers coded this data into the number of design elements the participants could freely recall from the infographics. On average, the participants were able to identify 2.79 design elements from the infographic (*SD* = 1.68, Minimum = 1, Maximum = 12).

The researchers also sought to understand what design elements the participants could recall when they were provided cues such as "what types of charts or graphs did you see in the infographic," "what colors did you notice throughout the infographic," "what icons, line elements, or images did you notice in the infographic." Similarly, the participants indicated they could recall, with a cue, elements such as graphs/charts, pie charts, pictographs, numbers and percentages, words/fonts, colors, and icons. To assign a numerical value, the researchers coded this data into the number of design elements the participants could recall with a cue from the infographics. On average, the participants were able to identify 8.76 design elements from the infographic (*SD* = 2.32, Minimum = 5, Maximum = 18), which indicates they could identify more design elements with a cue than they could freely.

Recall of Information from the Infographic. In addition to asking what the participants could recall about the design elements in the infographic, the researchers used questions to understand what information the participants could recall, both freely and cued, about the infographic. To do so, the participants were asked to list any types of content, data, themes, ideas, etc. that they could recall from the data. On average, the participants were able to freely recall 1.95 informational elements (*SD* = 1.17, Minimum = 0, Maximum = 8), from the infographic.

Later, participants were given a series of questions that provided cues to help them to remember the content found in the infographic. With the use of the cue, the participants, on average, were able to recall 3.08 information elements (*SD* = 3.08, Minimum = 0, Maximum 6).

Information Recognition. After completing the free and cued recall portions of the instrument, the participants were asked a series of true or false questions related to the information presented in the infographic. Based on the correct answers, the researchers calculated an information recognition score. On average, the participants had an average information recognition score of 6.36 (*SD* = 1.76, Minimum = 2, Maximum = 9), which indicates they were able to accurately recognize 6.36 pieces of information from the infographic.

RO2: Determine if the participants' recall (free & cued) of the design elements and information expressed in an infographic varied by the type of data visualizations used.

This objective sought to understand how the participants recall varied by type of data visualization present in the infographic. To determine if the free and cued recall significantly varied by data visualization type, a series of one-way ANOVAs were conducted. Overall, we found significant main effects for the type of data visualization on the participants' free recall of the design attributes, F(2, 237) = 5.64, p < .004, η^2 = .046 and cued recall of the design elements, F(2, 237) = 15.96, p <.001, η^2 = .120. According to Kotrlik et al. (2003) and Cohen (2016), these effect sizes represent a large effect. However, the researchers did not find significant main effects of the type of data visualization type on the participants' free recall of information, F(2, 237) = .74, p <.480, η^2 = .006 nor the cued recall of information, F(2, 237) = 1.85, p < .160, η^2 = .015, with small effects.

Table 2
One-Way Analysis of Variance for the Effects of Data Visualization Type on Free and Cued Recall of Design and Information

	Total (*n* = 238)		Bar Chart (*n* = 84)		Pie Chart (*n* = 74)		Pictograph (*n* = 80)				
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*F*(2,235)	*p*	η^2
Design											
Free Recall	2.79	1.68	2.57	1.39	2.49	1.45	3.29	2.03	5.64	.004*	.046
Cued Recall	8.76	2.32	7.85	1.89	8.69	2.20	9.78	2.46	15.96	.001*	.12
Information											
Free Recall	1.95	1.17	1.82	1.02	2.00	1.30	2.03	1.19	.74	.48	.006
Cued Recall	3.08	1.76	2.86	1.86	3.03	1.88	3.38	1.50	1.85	.16	.015

*Significance at the *p* < .05

To further examine the differences between the free and cued recall of the design attributes based on the type of data visualizations used in the message, the researchers evaluated the Bonferoni post hoc comparisons for each test. The Bonferroni post hoc comparisons revealed statistically significant differences in the mean scores of the free recall of the design elements of the data visualization types. Specifically, the researchers found significantly higher grand mean scores for the participants who viewed the pictograph (*M* = 3.29, *SD* = 2.03) than those who viewed the bar graphs (*M* = 2.57, *SD* = 1.39, *p* = .017,) and the pie charts (*M* = 3.29, *SD* = 2.03, *p* = .009).

Similar to the free recall of the design elements, Bonferoni post hoc comparisons revealed statistically significant differences between the types of data visualizations in the grand mean of the cued recall of the design elements. These tests suggested those participants who viewed the pictograph (*M* = 9.78, *SD* = 2.46) had significantly higher grand mean scores than those who viewed the bar charts (*M* = 7.84, *SD* = 1.88, *p* = <.001) and those who viewed the pie chart (*M* = 8.69, *SD* = 2.20, *p* = .007). There was also a statistically significant difference between those who viewed the pie charts and bar charts (*p* = .049).

RO3: Determine if the participants' information recognition varied by the type of data visualizations used.

As seen in Table 3, we first examined the mean scores for information recognition after the participants were exposed to the infographics. Visually, we saw the participants mean score was the highest when exposed to the pictograph (*M* = 6.88) in comparison to the pie chart (*M* = 6.41) and the bar chart (*M* = 5.83).

To determine if the information recognition significantly varied by data visualization type, a one-way ANOVA was conducted. The researchers found significant main effects for the type of data visualization presented in the stimuli on the participants information recognition, F(2,237) = 7.54, $p < .001$, $\eta^2 = .06$, a large effect (Cohen, 2016; Kotrlik et al. (2003). Bonferonni post hoc comparisons revealed those who viewed the pictograph (*M* = 6.88, *SD* = 1.61) had statistically significantly higher grand means for information recognition than those who viewed the bar chart (*M* = 5.83, *SD* = 5.83, $p < .001$).

Table 3
One-Way Analysis of Variance for the Effects of Data Visualization Type on Post-Test Information Recognition

	Total (*n* = 238)		Bar Chart (*n* = 84)		Pie Chart (*n* = 74)		Pictograph (*n* = 80)				
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	$F(2,235)$	p	η^2
Information Recognition	6.36	1.77	5.83	1.79	6.41	1.76	6.88	1.61	7.54	.001*	.060

Note: *Significance at the $p < .05$

Conclusions, Discussions, and Recommendations

Infographics are a unique way to capture viewers' attention and promote interest, understanding, and recall of communicated information regarding complex issues such as beef production sustainability (Smiciklas, 2012). Much literature has identified that infographics are effective communication mechanisms to increasing comprehension, enhancing critical thinking, and improving recall of information of complex and controversial issues (Adi & Ariesta, 2019; Smiciklas, 2012). However, limited research has been conducted to determine the effect of varying data visualization type on recall and information recognition, specifically within the agricultural sector. The findings from our study indicated significant differences in the participants ability to recognize information based on the type of data visualization presented in the infographic, and significant differences in the ability to recall design content in the infographics; however, we did not find significant differences in the participants ability to recall information based on the presented data visualization.

Recall of Design and Information

In order to create effective infographics, it is critical to understand what aspects of the infographic capture attention and influence recall and information recognition. Prior scholars have suggested graphs, pie charts, and pictographs to be the most compelling types of data visualizations to incorporate into an infographic (Brewer et al., 2012; Houts et al., 1997; Linden et al., 2014; Sullivan et al., 2016; Umanath & Scamell, 1998). Our study sought to identify whether or not there were significant differences in the participants ability to recall design elements and information from the varying types of data visualizations based on information about cattle sustainability. Within our study, we did not find significant differences between the type of data visualization and the recall of information; however, we did find significant differences based upon the recall of design elements to present the information.

This finding may be attributed to the psychological memory process as outlined by the LC4MP, which posits that humans have a limited capacity when processing information, and individuals will prioritize certain elements of a message over others (Fisher & Weber, 2020; Lang, 2009). Within the encoding process, or the initial stage of processing information, individuals will subconsciously process what aspects to encode from their information environment based on message features that stand out to them or information that aligns with their individual characteristics (Lang, 2000, Fischer et al., 2022). Visual elements that are visually salient, or stand out, to a receiver of information tend to be processed more frequently or critically (Fine & Minnery, 2009; Lohse, 1997). Increased attention may result from that fact that humans are inherently visual by nature. Within the current study, the message features provided by the pictograph may have elicited involuntary attention, which may have led to the increased encoding, storage, and retrieval of the design elements present in the infographic. Further, pictographs have been identified as one way to increase the understanding of quantitative information (Sullivan et al., 2016), especially with those with low numeracy skills. Perhaps our participants were more drawn to the icons and graphics present within the pictographs as they were more visually salient in comparison to the other types of data visualization techniques, and thus, they were able to identify its graphical elements.

Based on the fact the participants had a higher ability to recall design elements presented in the pictograph infographic, we were surprised to find no significant differences in the recall of the information presented between the three types of data visualizations. However, this finding is similar to the finding of Waller et al.'s (2020) study who did not find significant differences in information recall between narrative-based and infographic messages about genetic modification. Perhaps, since the participants were exposed to an infographic of any data visualization type, they were freely able to retrieve information from their repository of information to make judgements and recall the information just by being exposed to information on beef sustainability (Lang, 2000).

Information Recognition

Our findings from the information recognition questions were contradictory to our findings regarding information recall, and we did find significant main effects between type of data visualization and information recognition. Specifically, we found the participants were able to recognize information presented from the infographic with pictographs the most (M = 6.88), followed by pie charts (M = 6.41), and bar charts the least (M = 6.36). We attribute these findings to three reasons. First, Lang (2000, 2006) and Fischer et al. (2022) discussed encoding may be increased due to message features such as contrasting colors, text elements, and graphic elements. In this case, the pictographs may have elicited more attention, which led to the participants to encode and remember the design elements of the infographic, allowing them to recognize or remember more information. Second, scholars have indicated pictographs are useful in helping to effectively translate complex information into simplistic terms (Sullivan et al., 2016). Perhaps our participants were able to encode and associate their prior knowledge or understanding of the beef industry more easily, leading to higher retrieval rates, due to the nature of the pictograph. Third, the final reason may be due to increased attention to the pictographs due to the unique or novel nature of the data visualization technique. While pictographs have been widely used in infographics and visual communication, our participants may have been more exposed to data visualization techniques such as bar charts and pie charts in past experiences and did not place as much attention on these elements.

Limitations

We acknowledge there are limitations to this study. First, because this sample was limited to university undergraduate students, we are cautious to generalize beyond this group. The participants selected for this study do not represent all college students at Texas Tech or college students across the nation; instead, these participants represent a small group of college students and how they respond to data visualization types. However, the data provides insight on the use of the experimental conditions of the data visualization type on how the participants were able to recall design elements, recall information, and recognize information. Further, there are limitations due to the types of questions used in the study. For example, the free recall questions were open ended questions that were coded, cued recall was fill-in-the-blank, and information recognition was true or false. In each of these scenarios, the participants could take a lucky guess, thus providing researchers with the data. To minimize effects, we analyzed each of these separately and chose not to provide comparisons between each of the dependent variables. Additionally, we acknowledge the fair KR-20 score, and future research should seek to better the true or false questions. Perhaps one way to ensure better responses would be to add a "I don't know" question to eliminate guessing from the participants. Future studies examining recall may seek alternative methodological approaches for the gathering the data. Finally, given the online research setting and content, there is potential for response bias and guessing.

Recommendations for Practitioners & Educators

These results contribute to agricultural communication practices for practitioners who may incorporate infographic design in their communications strategy and also for educators who will be training students on how to create infographics and data visualization techniques. The findings of our study suggest the data visualization technique of the pictograph does cause a higher rate of information recognition in comparison to bar charts and pie charts. This finding is important when conveying complex information to viewers. Based on our findings, it is important to train future agricultural communicators and work with practitioners on data visualization techniques. Thus, we encourage practitioners to amplify their use of relevant data visualizations in their infographics.

Within agricultural communications curriculum, there is a strong need to train our next generation of agricultural communicators how to design and develop infographics and how to create compelling data visualizations. We recommend agricultural communications begin addressing this need by incorporating data visualization design into their graphic design courses, training students on the importance of using data visualization in their communications strategy and instilling the ability in our students to translate data into a data visualization.

Recommendations for Future Research

Regarding future research, our first recommendation is to expand the sample beyond the scope of college students. We recommend replicating this study with other student groups and/or within a nationwide public opinion panel, as varying levels of demographics and education levels may cause differences on how design elements and information is recalled or recognized in the post-test. It would be interesting to explore if education or numeracy level has an influence on the participants ability to recall and understand these messages as well.

This visual nature of this research also lends itself to an eye tracking study. An eye tracking study comparing data visualization types would allow researchers to pinpoint what elements elicited visual attention allocation from the viewers. Throughout our discussion, we have stated this element may have elicited visual attention allocation. The use of eye tracking methods would help agricultural communications scholars and practitioners to decide what type of data visualization captures the most attention. This study could also be used to make connections between visual attention and type of information understood by viewers. Overall, this study contributes compelling evidence that urges scholars and practitioners alike to implement and continue investigating the use of infographics and data visualization techniques in agricultural communications efforts.

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