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Applying Eye-Tracking Research in Education and Communication to Agricultural Education and Communication: A Review of Literature

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Abstract

The purpose of this integrative literature review was to synthesize the eye-tracking literature related to education and communication in the Social Sciences Citation Index (SSCI) to formulate a conceptual model and develop a research agenda that guides eye-tracking research in agricultural education and communication. To do so, we reviewed the literature to identify basic elements of eye-tracking research, examined specific variables related to eye-tracking research, and synthesized the findings into a conceptual model. We found and reviewed 77 articles published between 2010 and 2016 within education (56) and communication (21). Research implications for agricultural education included an examination of classroom management practices, a comparison of novice and experienced instructors, and an exploration of educational settings. Research implications for agricultural communication included tracking fixation and frequency of eye movement when viewing advertisements and understanding the relationship between brand placement and buying decisions. Synthesizing the research in education and communication, we identified the audiences, concepts, environments, and variables related to eye tracking that could be investigated within agricultural education and communication. In conclusion, we found a lack of agricultural education and communication studies cited in the SSCI, eye-tracking technology provides variables to support a multivariate approach in agricultural education and communication, and eye-tracking equipment is expensive, which may limit diffusion in some settings.

Keywords: eye-tracking, education, communication, agriculture, agricultural education, agricultural communication

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Introduction

Individuals learn and consume information using their eyes, and such information often becomes the "window into observers' visual and cognitive processes" (Salvucci & Goldberg, 2000, p. 71). From a physiological perspective, learning happens as neurological changes occur within the brain (Bruer & Greenough, 2001; Lichtman, 2001; Merzenich, 2001). As the brain processes information from the external environment, the brain decides how the processed information is used (Ormrod, 2008). The brain is a complex organ containing more than 100 billion neurons (Goodman & Tessier-Lavigne, 1997; Siegel, 1999), and those neurons are more likely to survive with access to new learning experiences (Gould, Beylin, Tanapat, Reevesm, & Shors, 1999; Leuner et al., 2004). Brain research shows learning does not stop during adolescence and learning/cognitive development is a lifelong process (Brown & Bjorklund, 1998; McCall & Plemons, 2001).

Within social science, scientists have studied cognitive development using eye-tracking (Lai et al., 2013). Havanki and VandenPlas (2014) suggested that "eye tracking collects information about eye movements and provides methods for analyzing a viewer's visual attention patterns" (p. 193). Eye tracking can be described using a) fixation, b) fixation duration, c) total fixation duration, d) saccade, e) smooth pursuit, f) regress, and g) scanpath. Fixation describes the process in which an individual pauses and focuses on one thing, and fixation duration and total fixation duration measure fixation length as one measures the total time of fixation during the trial and the other measures the total time of fixation on a specific region of interest (Havanki & VandenPlas, 2014). According to Havanki and VandenPlas (2014), the saccade describes the "rapid eye movements between fixations lasting between 10 ms and 100 ms," and the smooth pursuit describes the "slow eye movements that keep an image stationary on the fovea [central vision]" (p. 194). If an individual goes back to view previous objects, he or she is regressing. The scanpath is the profile describing an individual's fixations and saccades (Havanki & VandenPlas, 2014).

Eye tracking provides scientists with a method to investigate "behaviors that are difficult to articulate" (Havanki & VandenPlas, 2014, p. 200) using many different types of statistical tools. Eye-tracking studies produce mass amounts of data that are inclusive of multiple variables, but the data is limited to viewing patterns and does not include "attention, understanding, or interest" (Havanki & VandenPlas, 2014, p. 202). As an example, a scientist can collect as much as 600,000 data sets from one person in five minutes, which can be analyzed using ANOVA, MANOVA, and multi-linear regression (Havanki & VandenPlas, 2014). Therefore, using eye-tracking technologies provides scientists with opportunities to move beyond descriptive statistics and toward a multivariate approach (Mou & Shin, 2018; Rusch, Korn, & Gläscher, 2017; Stevens, 2009).

One of the disadvantages of eye tracking is the cost, both in terms of the monetary value of the equipment and the time and attention needed to conduct rigorous eye-tracking studies (Havanki & VandenPlas, 2014). Although the traditional eye-tracking technology is often an infrared camera attached to a computer monitor (Poole & Ball, 2006) or portable goggles, scientists must also have a desktop computer to analyze the large data sets and run multivariate statistics, a lab with space for the technology, a maintenance contract, and staff training (Havanki & VandenPlas, 2014). In addition, the technology is not free from technical issues, which require time and money to repair.

Yet, eye-tracking technology is effective when measuring "where a person is looking at any given time and the sequence in which the person's eyes are shifting from one location to another" (Poole & Ball, 2006, p. 211) as movements of the eye give insight to where individuals focus their attention (Just & Carpenter, 1980). Measuring the usability of visual-based information with eye-tracking technologies is objective in nature and can provide valuable information for designing and developing visual information or activities. For instance, measuring eye movements could lead to a better understanding of cognitive processes related to reading comprehension (Rayner, Chace, Slattery, & Ashby, 2006) and visual perception (Liversedge & Findlay, 2000).

Although eye-tracking technologies can measure how the brain receives and perceives visual stimuli, an important component of agricultural education and communication, studies using eye-tracking technologies as a method of measurement are limited within these disciplines. Yet, the potential for such studies is vast, substantiating the need for a synthesis of literature to guide future research in eye tracking and its applications in agricultural education and communication. Therefore, the purpose of this integrative literature review was to synthesize the eye-tracking literature related to education and communication in the Web of Science Social Sciences Citation Index (SSCI) in an effort to formulate a conceptual model and develop a research agenda that guides eye-tracking research in agricultural education and communication. The purpose of this study aligns with priority two of the 2016–2020 National Research Agenda—new technologies, practices, and production adoption decisions (Roberts, Harder, & Brashears, 2016). Three objectives guided the study:

1. Review the literature to summarize eye-tracking research in the broad disciplines of education and communication.
2. Identify variables related to eye-tracking research in the broad disciplines of education and communication.
3. Synthesize the findings to identify potential eye-tracking research studies within the profession and to develop a conceptual model for eye-tracking research in agricultural education and communication.

Method

We conducted an integrative literature review to establish a basis for investigating the use of eye-tracking technologies across agricultural education and communication. Torraco (2005) suggested integrative literature reviews "to address two general kinds of topics—mature topics or new, emerging topics" (p. 357). Therefore, because eye-tracking research is an emerging topic in agricultural education and communication, we chose an integrative literature review. As scientists in agricultural education and communication begin conducting eye-tracking research, Torraco (2005) suggested they "would benefit from a holistic conceptualization and synthesis of the literature to date" (p. 357). An integrative literature review in this context provides the profession with a conceptual model and research agenda to design empirical research.

Torraco (2005) defined the sample in an integrative literature review as the literature used to conduct the study and develop the findings. Thus, in describing the sample, we discuss our "strategy for selecting the literature" (p. 360), which included "how it was obtained ... and the criteria used for retaining or discarding the literature" (p. 360). To identify the literature base, we used the Web of Science Social Sciences Citation Index (SSCI). We chose the SSCI because it "delivers to users the most influential scientific research information from the 20th century" (Clarivate Analytics, 2018, para. 1). The database includes more than 6.4 million records from top journals across 55 disciplines of the social sciences (Clarivate Analytics, 2018). Therefore, because of the strength of the database and its vast depth, we found it to be the best place for locating the top research articles related to eye-tracking research in education and communication.

After choosing the SSCI, we set the parameters for the search as literature published between 2010 and 2016. We did so for three reasons: eye-tracking literature dates as far back as two to three decades, which could produce mounds of data; technology has changed significantly since eye tracking originated; and eye-tracking and biometrics research have evolved into a large phenomenon and spans across many disciplines. Because we were interested in the use of eye-tracking technologies as a research method and variables used in the studies, we determined the literature sample must include eye-tracking technologies as a method and must include measureable variables.

Once we set the above criteria, we searched the literature. The SSCI is easy to search and allows individuals to design the search as desired. Therefore, we set the parameters noted above within the database and began searching using our pre-established search terms. We searched the database for eye-tracking literature within education, communication, leadership, and extension to ensure our profession was represented holistically. We found substantial literature within the education and communication disciplines, but the literature was lacking in leadership and extension. The leadership literature was focused on business and did not make a clear connection to leadership education. Additionally, literature related to extension was non-existent in the database. Therefore, we chose not to include leadership or extension and chose to focus on education and communication. It is important to note we searched in the overarching disciplines of education, communication, leadership, and extension because we sought to identify eye-tracking studies in broader disciplines beyond agriculture.

First, we searched the educational database. We searched the database using the keyword *eye-tracking and education*, which yielded 85 articles. SSCI includes a discipline list that allows an individual to search a specific discipline, but we were not able to do so because the SSCI did not have one category for education. Therefore, we simply used *eye-tracking and education* as a way to pull articles from all types of journals. Of the 85 articles, we excluded 29 articles that were not empirical research (e.g., editorials) or were not related to education or learning (e.g., surgical procedure), leaving 56 usable articles.

Second, we searched the communication literature base. For communication, we searched communication specific journals because the SSCI had one category for communication. Choosing this category helped us narrow our search to communication-specific journals. Using the keyword *eye-tracking* yielded 33 articles. We did not include communication in the search term because we narrowed our search to communication when we chose the communication category, which the education search did not allow us to do. We excluded 12 articles from the communication search because they were not empirical research articles, which left us with 21 usable articles. We found one article that was duplicated in our searches between education and communication. We included this article in both tables as it was generated independently using the search criteria set forth for each discipline.

Third, we searched the SSCI database for articles related to leadership education. We searched the database using *leadership and eye-tracking* because the SSCI database did not have a category for leadership. Our search did not yield any articles related to leadership education—as the articles focused more on business or educational leadership.

Fourth, we searched the SSCI database for extension. We searched the database using *extension and eye-tracking* because the SSCI database did not have an extension category. Our search did not yield any articles related to extension. Many of the articles included the word *extension* but were not focused in the context of 1862 land-grant *extension*.

Therefore, our search of the SSCI database for articles related to education and communication yielded 118 articles that had potential to be included the study. We read each of the 118 articles and noted each one's applicability to education or communication. During this stage, we excluded 41 articles from the sample because they did not meet the criteria. Therefore, we had 77 usable eye-tracking articles related to education and communication.

We synthesized the purpose of each article and identified the measurable variables. We classified eye-tracking variables as fixation, saccade, or both according to the type of eye movement measured (Lai et al., 2013). Additionally, we classified the scales of measurement used during eye-tracking as temporal, count, spatial, or any combination of the three (Lai et al., 2013). Torraco (2005) noted "Various aspects of the literature can be reviewed with more or less scrutiny" (p. 361). Therefore, we established our literature review by analyzing the literature, examining the variables, and synthesizing the findings.

We formulated the research questions based on the potential direction for new emerging research and on prior eye-tracking research conducted within the broad disciplines of education and communication. Such methods follow Torraco's (2005) recommendations as "the research agenda should pose provocative questions (or propositions) that give direction for future research" (p. 363). Furthermore, to develop the conceptual model, we reviewed current studies in education and communication and in the broad agricultural education profession to create a path for the future of eye-tracking research within the profession. This, too, follows Torraco's (2005) recommendations: "Alternative models or conceptions proposed by the author should be derived directly from the critical analysis and synthesis provided … [establishing] new ways of thinking about the topic addressed" (p. 363).

In reporting, we organized the data according to the disciplines of education and communication. Within each discipline, we provided a review of relevant literature and presented the research variables. We synthesized our findings from across the literature and presented a conceptual model for understanding how eye-tracking research fits into agricultural education and communication. We addressed objectives one and two for each area of study before addressing the collective implications for agricultural education and communication in objective three.

Findings

Objective 1: Review of Literature

Education. Within the last six years, eye-tracking literature spanned a variety of emphasis areas in education. Some studies are specific to the traditional classroom setting while others are a broader examination of education, including consumer education (Bonsmann, Celemin, & Grunert, 2010; Graham, Heidrick, & Hodgin, 2015; Samant & Seo, 2016) and health literacy (Mackert, Champlin, Pasch, & Weiss, 2013; Miller & Cassady, 2012). As the focus of this literature review, we divided traditional education studies into two groups: studies with students as the participants and studies with teachers as the participants.

Eye-tracking studies using students as the participants often explored students with learning disabilities. Specifically, Berget and Sandnes (2015) and Berget, Mulvey, and Sandnes (2016) investigated the effects of dyslexia on student performance of information searches using web-based search engines. They discovered dyslexia had a negative impact on search performance. Results from these studies have the potential to improve future web layout and navigation for students (Berget et al., 2016). In addition, recent studies also analyzed gaze patterns of students with autism and how autism relates to social difficulties and challenges (Falck-Ytter, 2015; Hanley et al., 2015). These studies can provide valuable information to teachers and administrators on the optimum learning conditions for students with a variety of learning disabilities.

Additionally, scientists have studied image interpretation and its effect on student cognitive load (Mills et al., 2016) by examining pupil dilatation in students (Stuijfzand et al., 2016) and studied cognitive engagement of students during science instruction (Miller, 2015). Often in conjunction with the variable of cognitive load, scientists explored mental rotation because of the manifestation of mental rotation in the participants' eyes (Roach, Fraswer, Kryklywy, Mitchell, & Wilson, 2015; Xu & Franconeri, 2015). However, despite recent developments and applications for eye-tracking technology, limitations still exist. Miller (2015) found eye-tracking measures were still insufficient to gauge mind-wandering and emotional arousal, which are two areas in need of further exploration in studies pertaining to cognitive engagement and cognitive load.

The majority of eye-tracking studies in education were conducted in the content areas of English and reading with some science education literature related to student comprehension of content. Cullipher and Sevian (2015) and Williamson, Hegarty, Deslongchamps, Williamson, and Schultz (2013) explored students' reasoning and understanding of complex chemistry concepts. They postulated eye-tracking could be a useful method to reveal underlying assumptions about science concepts that are more difficult for students to comprehend. Furthermore, Kragten, Admiraal, and Rijlaarsdam (2015) measured fixation time on interest areas to explore students' brain activity while examining biological diagrams (e.g., photosynthesis). Students found meaning-making with the process arrows in the diagrams to have significant impact on their comprehension (Kragten et al., 2015). Any education discipline in which visual representations are crucial for learning and understanding could benefit from further examination.

Other scientists used different branches of science when studying eye tracking, including Chen et al. (2014) who examined student computer-based assessment performance in physics, and Tsai, Hou, Lai, Liu, and Yang (2012) who researched university students how students answered multiple choice science problems. Finally, elementary science combined science and reading to examine fourth grade students' cognitive processes and learning strategies for reading textbooks in biology. Combining reading comprehension with particular content areas is an innovative way to explore the impact of readings and resources (Jian, 2015). Agricultural education could serve as the context for a similar study focusing on commonly used textbooks and other resources specific to the discipline.

In addition, scientists conducted multiple studies in healthcare professional education fields: general medicine (Stuijfzand et al., 2016), radiology (Kok et al., 2016), paramedicine (Mills et al., 2016), occupational therapy (MacKenzie & Westwood, 2015), anatomy (Zumwalt, Iyer, Ghebremichael, Frustace, & Flannery, 2015), and anesthesia (Schulz et al., 2011). As a result, multiple healthcare education settings have incorporated eye-tracking technologies to improve educational techniques in their training programs. Browning et al. (2016) claimed eye-tracking technology provided a unique avenue for evaluating clinical practice and had the potential to provide additional perspectives on clinical situations, leading to improved learning. Mills et al. (2016) claimed eye-tracking technologies combined with other measurements, such as heart rate, could measure beginning students' cognitive load and anxiety during clinical simulations.

Research with teachers as the participants used eye-tracking technologies to measure classroom and behavior management strategies as variables. For example, Cortina, Miller, McKenzie, and Epstein (2015) compared novice and expert teachers and discovered expert teachers' possessed superior classroom monitoring skills. Based on this, they recommended using mobile technology to provide feedback during the professional development of practicing teachers and suggested further exploration into deciphering the meaning between teacher eye movements and classroom interactions and atmosphere (Cortina et al., 2015). Wolff, Jarodzka, van de Bogert, and Boshuizen (2016) explored novice and experienced teachers' perceptions of various classroom management scenarios. Experienced teachers were more focused on areas of the classroom where students provided relevant information or where an incident was more likely to occur while novice teachers scattered their focus throughout the classroom. They postulated effective classroom management may not be based on teachers seeing the incident but if they have the experience to decide if the incident is worthy of attention (Wolff et al., 2016).

Furthermore, other scientists explored classroom management of novice and experienced teachers, many using think-aloud techniques in conjunction with eye-tracking techniques (van de Bogert, van Bruggen, Kostons, & Jochems, 2014). Dougusoy-Taylan and Cagiltay (2014) analyzed expert and novice teachers' concept mapping processes, which has the potential to inform teacher educators on ways to instruct preservice teachers. The comparison of classroom management techniques was not limited to secondary education. Scientists within medical education have also conducted studies examining how experts comprehend medical visualizations and they transfer their knowledge of those visualizations (Gegenfurtner & Seppanen, 2013).

In summary, eye-tracking research can contribute to the evaluation of educational strategies by shedding light on students' learning and behavior in various educational disciplines, including reading, science and, potentially, agriculture. Recent technological advancements in eye-tracking hardware, software, and equipment have allowed for a decrease in price, rendering this as a more feasible tool. Additionally, the movement from lab-confined, eye-tracking testing to the use of glasses in the field has allowed for more creative studies capturing eye-tracking in authentic environments and is applicable to a variety of age ranges and educational occupations.

Communication. Eye-tracking studies in communication began in the late 1980s and focused primarily on print media. In recent years, however, the increased use of digital media has led to an increased use of eye-tracking research. Investigating an individual's eye movements "provide[s] an unobtrusive, sensitive, real-time behavioural [*sic*] index of ongoing visual and cognitive processing" (Henderson & Ferreira, 2004, p. 18). Although eye-tracking is an unobtrusive, objective, and direct method to investigate media consumption and measure visual elements of media (Boerman, van Reijmersdal, & Neijens, 2015), it fails to tell us why people consume media the way they do (Leckner, 2012).

The human mind is fascinating (Palmer, 1999) as the goals, interests, and expectations of an audience determines where their eyes focus on the message and how they consume the information (Boeriis & Holsanova, 2012). Messages often enter the human mind through the senses and particularly through the eyes where they are grouped, separated, segmented, identified, distinguished, perceived, and recognized (Palmer, 1999). However, because many eye-tracking studies within communications occur in fabricated settings, the participants may not behave as they would in real life situations (Leckner, 2012), which is a downfall of using staged settings for empirical research.

Memory is an important component of communication and, more specifically, advertising effectiveness (Delattre & Colovic, 2009; Jeong, Kim, & Zhao, 2011; Lee, Li, & Edwards, 2012). Advertising and health communication are two areas of communication that use eye-tracking techniques as a primary data collection method because of the importance of attention, retention, and recall. As an example, Bol et al. (2016) sought to understand differences, if any, between attention and recall in younger and older populations. Their findings revealed older adults were more attentive and recalled more information as their exposure to text increased while younger adults were more attentive and recalled more information when exposed to cognitive illustrations. Yet, illustrations did not increase the time participants spent on the website.

Additionally, a 2015 study by Boerman et al. "investigate[d] the influence of different ways of disclosing brand placement on viewers' visual attention, the use of persuasion knowledge, and brand responses" (p. 196). Brand placement has caught the attention of many stakeholders (e.g., academics, policy makers) because brand placement can distract readers (Cain, 2011). Boerman et al.'s (2015) results indicated the combination of text and the brand logo was most effective in increasing brand recognition as logos alone were not enough to increase participants' recognition of brands attracting visual attention. Similarly, in a health communication study, Morrow et al. (2012) found pictures were an important tool in educating and communicating with low-literacy individuals as the pictures improved individuals' comprehension of text. Yet, to improve comprehension, pictures must be relevant to the text.

Likewise, Mackert et al. (2013) sought to "investigate whether those with different health literacy capacities might view information in different ways" (p. 192). Specifically, they were interested in why some individuals have low health literacy and some have high health literacy even though the two groups had varying levels of socioeconomic statuses. This interest lead to their hypothesis: People with low health literacy view health information differently than those with high health literacy. Mackert et al. (2013) found that poor health literacy skills correlated with "greater duration of fixation on non-relevant information" (p. 192). The study's outcome can guide practitioners as they design information to serve populations with varying socioeconomic statuses.

Objective 2: Variables Measured Using Eye-Tracking

Eye-tracking measurements vary depending on the purpose of the research and the discipline. Lai et al. (2013) recognized two dimensions to measure eye movement: types of eye movement and scales of measurement. Eye movement is classified as fixation (consistent or stable eye movement), saccade (eye movement between fixations), or a combination of the two (Lai et al., 2013). Additionally, eye movement is measured using three scales: (a) temporal measures the amount of time spent focusing on a specific area; (b) spatial measurement is concerned with "locations, distances, directions, sequences, transactions, spatial arrangement or relationships of fixations or saccades" (p. 93); and (c) count refers to the frequency of eye movements taking place (Lai et al., 2013).

Education. Of the studies conducted in the broad discipline of education and published in journals specific to the SSCI, we found 56 studies that measured the fixation variable and 12 that measured the saccade variable. Of the 56 studies measuring the fixation variable, 50 measured temporal, 46 measured spatial, and 26 measured count (see Table 1).

Table 1

Purpose of Study and Variables Measured for Education Studies Using Eye-tracking Methods

ID	Authors	Purpose	Variables Measured
1	Abrahamson, Shayan, Bakker, and van der Schaaf (2015)	"Empirically evaluate theoretical models accounting for the emergence of concepts from situated sensorimotor activity" through "presymbolic manipulation tasks designed to foster grounded meanings for the mathematical concept of proportional equivalence" (p. ab).	Fixation – temporal, spatial
2	Balsev et al. (2012)	"Investigate visual attention and concomitant cognitive processes of clinicians diagnosing authentic pediatric video cases" (p. ab).	Fixation – temporal, spatial
3	Bansback, Li, Lynd, and Bryan (2014)	"Utilize principles of behavioral economics to develop a computer application that presents information from conventional decision aids in a way that reduces these errors, subsequently promoting higher quality decisions" (p. ab).	Saccade, Fixation – temporal, spatial
4	Berget et al. (2016)	Investigate "whether the inclusion of icons in search user interfaces enhances performance among dyslexics" in visual search tasks (p. ab).	Saccade, Fixation – temporal, spatial, count
5	Berget and Sandnes (2015)	"Identify effective search interface design guidelines that benefit dyslexic users" (p. ab).	Fixation – temporal, count
6	Bonsmann et al. (2010)	"Determine how nutrition labeling can affect dietary choices, consumer habits, and food-related health issues" (p. ab).	Fixation – temporal
7	Chen et al. (2014)	"Investigate whether human eye movement dynamics can predict computer-based assessment performance (accuracy of response) in different presentation modalities (picture vs. text)" (p. ab).	Saccade, Fixation – temporal, spatial, count
8	Chen et al. (2016)	"Investigate the relationship between affect and e-learning and to design an intelligent e-learning system that interacts naturally with learners" (p. 217).	Fixation – spatial, temporal
9	Cortina et al. (2015)	"Investigate whether the distribution of the fixation among students was associated with dimensions of the high inference CLASS [classroom assessment scoring system] dimensions of instructional quality" (p. 394).	Fixation – temporal, spatial

Table 1 (continued)

Purpose of Study and Variables Measured for Education Studies Using Eye-tracking Methods

ID	Authors	Purpose	Variables Measured
10	Cullipher and Sevian (2015)	"Use eye-tracking, along with a think-aloud protocol, to examine how students look at the infrared (IR) spectra of two substances and relate the molecular structures of these substances to their respective IR spectra" (p. 1998).	Fixation – spatial
11	Dogusoy-Taylan and Cagiltay (2014)	"Explore how designated experts (subject experts with extensive experience in science education and concept mapping) and novices (pre-service teachers) establish concept map (CM) development processes while considering their cognitive processes" (p. ab).	Fixation – temporal, spatial, count
12	Ettenhofer, Hershaw, and Barry (2016)	"This study was conducted to examine a novel approach to multimodal assessment of visual attention incorporating concurrent measurements of saccadic eye movements and manual responses" (p. ab).	Saccade, Fixation
13	Falck-Ytter (2015)	"Non-invasive eye-tracking technology was used to quantify the amount of time spent looking at another person's face during face-to-face communication in children with ASD [Autism Spectrum Disorder]" (p. ab).	Fixation – temporal
14	Gegenfurtner and Seppanen (2013)	Investigate "whether expert performance and its underlying processes transfer to novel tasks within a domain" (p. ab).	Fixation – temporal, count, spatial
15	Graham et al. (2015)	"This study quantifies Nutrition Facts and front-of-package nutrition label viewing among American adult consumers" (p. ab).	Fixation – temporal, spatial
16	Hancock and Ste-Marie (2013)	"Examine gaze behaviors, decision accuracy, and decision sensitivity (using signal detection analysis) of ice hockey referees of varying skill levels in a laboratory setting" (p. ab).	Fixation – temporal, count
17	Hanley et al. (2015)	"Use eye-tracking during real social interaction to explore attention to social cues (e.g. face, eyes, mouth) and links to social awareness in a group of cognitively able University students with autism spectrum disorder and typically developing students from the same University" (p. ab).	Fixation – spatial
18	Harley, Poitras, Jarrell, Duffy, and Lajoie (2016)	Compare "undergraduate students' emotions and learning outcomes during a guided historical tour using mobile AR [augmented reality] applications" (p. ab).	Saccade, Fixation – temporal, spatial

Table 1 (continued)

Purpose of Study and Variables Measured for Education Studies Using Eye-tracking Methods

ID	Authors	Purpose	Variables Measured
19	Jarodzka et al. (2012)	Answer the following questions, "Can displaying an expert's eye movements in modeling examples be beneficial for learning, and if so, which type of display is more effective in terms of attentional guidance and learning?" (p. 817).	Fixation – temporal, spatial, count
20	Jian (2015)	Investigate "students' reading strategies and comprehension of illustrate biology texts in relation to adult readers' performance" (p. ab).	Saccade, Fixation – temporal, spatial, count
21	Kessels and Ruiter (2012)	"Examine the amount of attention allocation to risk information and coping texts on cigarette packages" (p. 2).	Fixation – temporal, spatial
22	Kok, de Bruin, Leppink, van Merrienboer, and Robben (2015)	Investigate "the effectiveness of three comparison techniques in medical students, whom we invited to compare cases of the same disease (same-disease comparison), cases of different diseases (different-disease comparison), disease images with normal images (disease/normal comparison), and identical images (no comparison/control condition" (p. ab).	Saccade, Fixation – temporal, spatial
23	Kok et al. (2016)	Investigate "the relationship between systematic viewing, coverage, and diagnostic performance" (p. ab).	Fixation – temporal, spatial, count
24	Kragten et al. (2015)	"Examined students' learning activities while studying process diagrams, related to their resulting comprehension of these diagrams" (p. ab).	Saccade, Fixation – temporal, spatial, count
25	MacKenzie and Westwood (2015)	"Determine if differences exist in safety ratings and eye movements between occupational therapists and non-trained matched individuals while viewing domain-specific and non-domain specific images" (p. ab).	Saccade, Fixation – temporal, spatial
26	Mackert et al. (2013)	"Explore how individuals with different levels of health literacy visualize health-related information" (p. ab).	Fixation – temporal, count
27	McEwen and Dube (2015)	"Explore the relationship between a user's engagement with tablet computers and that user's cognitive load" (p. 10).	Fixation – temporal, spatial, count

Table 1 (continued)

Purpose of Study and Variables Measured for Education Studies Using Eye-tracking Methods

ID	Authors	Purpose	Variables Measured
28	Miller (2014)	Explore "the effects of age and preferences on first, the degree to which individuals pay attention to weights and % DVs when evaluating healthfulness of NFPs; and second, the effectiveness of attention, assessed through examination of associations between attention and accuracy" (p. 1208).	Fixation – temporal, spatial
29	Miller and Cassady (2012)	"Using eye-tracking methodology, examined strategies associated with deciding which of two NFPs, presented side-by-side, was healthier. We examined associations among strategy use and accuracy as well as age, dietary modification status, knowledge, and motivation" (p. ab).	Fixation – temporal
30	Mills et al. (2016)	"Test the assumption underlying the progressive continuum of fidelity for simulation-based education of healthcare students" (p. 11).	Fixation – temporal, spatial, count
31	Morrow et al. (2012)	"Explore knowledge effects on comprehension of multimedia health information by older adults" (p. ab).	Fixation – temporal, spatial
32	Mu (2010)	"Explore video notetaking behaviors and to examine the effect of the new Smartlink design" (p. ab).	Fixation – temporal, spatial
33	Nussembaum and Amso (2016)	Examine "the effects of increasing the social interactivity of television on children's visual attention and word learning" (p. ab).	Fixation – temporal, spatial
34	O'Meara et al. (2015)	"Determine whether the use of eye-tracking technology combined with video debriefing techniques has the potential to improve the quality of feedback and enhance situation awareness (SA) in simulated settings and second to determine students' satisfaction towards simulated learning" (p. ab).	Fixation – spatial
35	Popelka and Brychtova (2013)	"Analyze differences between cognition of classical orthogonal maps and their equivalents made with use of 3D visualization" (p. 241).	Saccade, Fixation – temporal, spatial
36	Rau, Michaelis, and Fay (2015)	"Identify learning processes that are important for connection making between multiple graphical representations in chemistry," "identify visual attention behaviors that indicate productive learning processes as students make connections," and "improve students' learning of important concepts in chemistry" (p. 461).	Fixation – temporal, spatial, count

Table 1 (continued)

Purpose of Study and Variables Measured for Education Studies Using Eye-tracking Methods

ID	**Authors**	**Purpose**	**Variables Measured**
37	Rihn, Khachatryan, Campbell, Hall, and Behe (2015)	"Investigate the effect on plant attributes on consumer purchase likelihood for indoor foliage plants" (p. ab).	Fixation – spatial, count
38	Roach et al. (2015)	"Explore eye movements and MRA [mental rotation ability], during the completion of an adapted, electronic mental rotations test (EMRT) where no time limits are imposed" (p. 358).	Fixation – temporal, spatial, count
39	Samant and Seo (2016)	"Determine the effect of label education on consumers' purchase behavior" (p. ab).	Fixation – temporal, count
40	Schulz et al. (2011)	Investigate "whether eye-tracking and heart rate registration can be used to assess anesthetists' workload fluctuations during full-scale simulator sessions" (p. 44).	Saccade, Fixation – temporal, spatial
41	Stuijfzand et al. (2016)	Investigate "whether measures inherent to image interpretation, i.e. human-computer interaction and eye-tracking, relate to cognitive load" (p. ab).	Fixation – temporal, spatial
42	Tang, Kirk, and Pienta (2014)	Investigate "complexity factors in stoichiometry word problems", and identify, "students' problem solving protocols by using eye-tracking technology" (p. ab).	Fixation – temporal, count
43	Tang and Pienta (2012)	"Explore the effect of problem difficulty and cognitive processes when students solve gas law word problems" (p. ab).	Fixation – temporal, spatial
44	Tsai et al. (2012)	"Examine students' visual attention when solving a multiple-choice science word problem" (p. ab).	Fixation – temporal, spatial
45	van Amelsvoort, van der Meji, Anjewierden, and van der Mej (2013)	"Assess the influence of perceptual cues on reading behavior and subsequent retention" (p. ab).	Fixation – temporal, spatial, count
46	van den Bogert et al. (2014)	"Investigate teachers' visual perception and detection of classroom events" (p. ab).	Fixation – temporal, spatial, count

Table 1 (continued)

Purpose of Study and Variables Measured for Education Studies Using Eye-tracking Methods

ID	**Authors**	**Purpose**	**Variables Measured**
47	van Gog, Verveer, and Verveer (2014)	Compare the “effects on learning of observing a video modeling example in which the model’s face is visible or not visible and recording participants’ eye movements while viewing the videos” (p. 324).	Fixation – temporal, spatial, count
48	van Silfhout, Evers-Vermeul, Mak, and Sanders (2014)	“Focuses on the effects of two text features— coherence marking and layout—on students’ cognitive processes and mental representations” (p. 1037).	Fixation – temporal
49	Walhout et al. (2015)	Investigate “the effects of two types of navigational support, information tasks with different complexity levels, and learner gender on navigation behavior through HLEs, visual processing of the navigation menu (as measured by eye-tracking), and task performance” (p. 220).	Fixation – temporal, spatial, count
50	Wang, Chen, and Lin (2014)	“Examine the spatial abilities of students using eye-movement tracking devices to identify and analyze their characteristics” (p. ab).	Fixation – temporal, spatial, count
51	Williamson et al. (2013)	Examine “students’ use of ball-and-stick images versus electrostatic potential maps when asked questions about electron density, positive charge, proton attack, and hydroxide attack with six different molecules” (p. ab).	Fixation – temporal, spatial
52	Wolff et al. (2016)	Investigate “the extent to which experience in the classroom influences teachers’ visual perception and subsequent viewing strategies” (p. 248).	Fixation – temporal, spatial
53	Xing and Isaacowitz (2011)	“Examine young adults’ and highly educated older adults’ attention toward two types of decision-relevant information: heuristic cue vs. factual cues” (p. ab).	Fixation – count
54	Xu and Franconeri (2015)	Explore visual cognition by testing the participants’ “capacity for keeping features attached to the correct parts during mental rotation” (p. 1242).	Saccade, Fixation – temporal, spatial
55	Zhang-Kennedy, Chiasson, and Biddle (2016)	Answer the question, “Do integrated visual-textual-interactive education material form a memorable and persuasive approach for computer security understanding by altering user perception and improving user behavior?” (p. 215).	Fixation – temporal, spatial, count

Table 1 (continued)

Purpose of Study and Variables Measured for Education Studies Using Eye-tracking Methods

ID	**Authors**	**Purpose**	**Variables Measured**
56	Zumwalt et al. (2015)	"Investigate whether changes in gaze patterns reflect learning by students in a medical gross anatomy course" (p. ab).	Fixation – temporal, spatial, count

Communication. Of the studies conducted in the broad discipline of communication and published in journals specific to the SSCI, we found 21 studies that measured the fixation variable and six that measured the saccade variable. Of the 21 studies measuring the fixation variable, 20 measured temporal, 14 measured spatial, and 11 measured count (see Table 2).

Table 2

Purpose of Study and Variables Measured for Communication Studies Using Eye-tracking Methods

ID	Authors	Purpose	Variables Measured
1	Bassett-Gunter, Latimer-Chueng, Ginis, and Castelhano (2014)	Investigate "gain-framed versus loss-framed physical activity messages following exposure to health risk information" (p. ab).	Fixation – temporal
2	Boerman et al. (2015)	"Use eye-tracking to estimate viewers' visual attention while watching a program" (p. 197).	Saccade, Fixation – temporal, spatial
3	Bol et al. (2016)	"Investigate the relationship between attention and recall among younger (<65 years) and older (≥65 years) adults" (p. ab).	Fixation – temporal, spatial
4	Cooke (2010)	Determine "how CTA [current think-aloud protocol] functions within usability test settings," and "address three areas that have yet to be fully explored: verbalized accuracy, verbalized content, and silence/verbal fillers" (p. 204).	Saccade, Fixation – temporal
5	Elling, Lentz, and De Jong (2012)	Compare concurrent think-aloud protocols and eye-tracking observations as use of a valid methodology for types of verbalizations.	Saccade, Fixation – temporal, spatial, count

Table 2 (continued)

Purpose of Study and Variables Measured for Communication Studies Using Eye-tracking Methods

ID	Authors	Purpose	Variables Measured
6	Gidlöf, Holmberg, and Sandberg (2012)	"Investigate (1) potential exposure, (2) actual exposure, and (3) perceived exposure to online advertising in Swedish 15-year-olds" and "capture the teenagers' natural online behavior" (p. ab).	Fixation – temporal, spatial, count
7	Hartmann, Apaolaza, and Alija (2013)	"Presents a theoretical framework hypothesising [*sic*] that nature imagery presented in an advertisement enhances cognitive advertising message elaboration and memory" (p. ab).	Fixation – temporal, count
8	Jöckel, Blake, and Schlütz (2013)	"Evaluate the effects of an increase in salience factors of age-rating labels for video games and movies" (p. 91).	Fixation – temporal, spatial
9	Lenzner, Kaczmirek, and Galesic (2011)	"Use eye-tracking as a more direct method to examine whether [survey] comprehension is indeed impeded by these text features" and "examine whether these text features have different effects for different types of questions" (p. 362).	Saccade, Fixation – temporal, count
10	Mackert et al. (2013)	"Understand how individuals of different health literacy capacities find and use health information presented in one of the available health literacy assessment instrument" (p. 186).	Fixation – temporal, count
11	Mangiron (2016)	"Determine what type of subtitles would be most suitable for video games, given their interactive and ludic nature, based not only on users' preferences but also on quantitative data obtained with an eye-tracking technology" (p. ab).	Fixation – temporal
12	Matukin, Ohme, and Boshoff (2016)	"Explore consumers' subconscious responses in relation to their eye fixation at a static advertising image, in this case a DVD cover" (p. ab).	Fixation – temporal
13	Moore, Liebal, and Tomasello (2013)	"Differentiate between the features of an action that would lead children to interpret it as communicative" (p. 64).	Saccade, Fixation – spatial
14	Morrow et al. (2012)	"Explore knowledge effects on comprehension of multimedia health information by older adults (age 60 or older)" (p. ab).	Fixation – temporal, spatial, count

Table 2 (continued)

Purpose of Study and Variables Measured for Communication Studies Using Eye-tracking Methods

ID	Authors	Purpose	Variables Measured
15	Rieger, Bartz, and Bente (2015)	Investigate if context congruency increased the impact of banner advertisement	Fixation – temporal, spatial, count
16	Smit, Boerman, and Van Meurs (2015)	"Examine the role of direct context in the competition for attention to magazine advertising" (p. 217).	Fixation – temporal, spatial, count
17	Steele et al. (2013)	"Test a neuroscience-informed model of immersive-versus flexible audience engagement and demonstrates television's heightened ability to sustain nonconscious emotional response over online viewing" (p. ab).	Fixation – temporal, spatial, count
18	Turner, Skubisz, Pandya, Silverman, and Austin (2014)	"Explore the degree to which people pay visual attention to the information contained in food nutrition labels and front-of-package nutrition symbols" (p. ab).	Fixation – temporal, spatial
19	Van Cauwenberge, d'Haenens, and Beentjes (2015)	"Examine the effect of an innovative way of structuring news on the tablet that mimics mobile news behaviors on attention and public affairs knowledge acquisition" (p. 427).	Fixation – temporal, spatial
20	Westerwick, Kleinman, and Knobloch-Westerwick (2013)	"Examine impacts of attitude consistency, attitude importance, and source credibility on selective exposure to political messages and subsequent attitude accessibility" (p. ab).	Fixation – temporal, spatial, count
21	Yin and Kuo (2013)	"Investigate how direct and indirect speech acts may influence language comprehension in the setting of communication problems inherent in IS [information system] projects" (p. 227).	Saccade, Fixation – temporal, spatial, count

Objective 3: Research Implications for Agricultural Education and Communication

Research implications for agricultural education. Implementing eye tracking as a measurement tool in agricultural education has many potential benefits and could provide a rigorous dimension to our agricultural education literature base. One area of potential research is examining classroom management practices for student teachers and practicing teachers. Eye-tracking technologies have advanced beyond the computer lab setting and become increasingly mobile with eyeglasses technology and smart phone devices. This could allow for research that investigates where agriculture teachers gaze in a classroom, how much time they spend looking at particular students, and potential *blind spots* in their gaze. Many education studies in reading and science have used this technology to compare novice and experienced instructors (Dougusoy-Taylan & Cagiltay, 2014; van de Bogert et al., 2014).

As numbers of students in secondary agricultural education continue to grow, classroom management becomes more challenging, which necessitates research on effective management strategies. To better prepare future teachers, learning from experienced teachers' interpretation of classroom events could be incredibly useful and lead to more purposeful instruction. Additionally, there is potential for examining classroom management at the university level. Many teacher preparation programs engage in micro-teaching simulations with senior-level students. Current studies in the agricultural education field have investigated the teaching resiliency of preservice, agriculture teachers by measuring heart rate and stress (Thieman, Henry, & Kitchel, 2012; Thieman, Marx, & Kitchel, 2014). Eye-tracking could be another quantitative measurement to add to this area of research and could lead to more experimental or quasi-experimental research designs.

Using eye-tracking as a measurement also opens the door for collaboration with other disciplines, including cognitive psychology, science education, and English education, as many of them have used such methods for decades. Some environments, such as the classroom shop, land lab, and school farm, are unique educational settings to agricultural education and could produce beneficial research on the classroom management required of teachers in these settings. Additionally, the overlap between education and communication lends itself to opportunities to collaborate across our individual disciplines. Studies in the review of literature that focused on consumer education (Bonsmann et al., 2010; Graham et al., 2015; Samant & Seo, 2016) could be starting points for designing research studies that combine education and communication.

Research implications for agricultural communication. As mentioned earlier, scientists within health communications and advertising have conducted expansive eye-tracking research as it relates to recall, retention, and attention. In the context of agricultural communications, recall, retention, and attention are important as much of what agricultural communicators do centers on producers' and consumers' abilities to pay attention to, recall, and retain information related to the world's food and fiber supply. Therefore, eye-tracking research could be used to track fixation duration and/or count of consumers viewing television advertisements related to food and fiber consumption, of farmers reading farm magazines and their product advertisements, of consumers reading food labels and making purchasing decisions (Turner et al., 2014), of producers' and consumers' internet access and use, and of producers and consumers allocating attention to different sources of information (Morrow et al., 2012). Additionally, eye-tracking research would be instrumental in understanding if brand placement impacts consumers' intention to buy food products and if brand placement impacts differ based on types of food (e.g., organic or conventional; fruits or vegetables; healthy or unhealthy). The application of eye-tracking research in agricultural communications is abundant, and the aforementioned studies are just the beginning of the possibilities.

Conceptual model for conducting eye-tracking research in agricultural education and communication. Synthesizing the research scientists have conducted in the broader disciplines of education and communication, we have identified the conceptual areas scientists in agricultural education and communication could investigate using eye-tracking technologies (see Figure 1). Within agricultural education, we believe two audience bases exist: teachers and students. In studying those audiences, we believe the eye-tracking technologies would be most effective as scientists investigate the effects that learning strategies have on students—cognition and behaviors, task performance, affective, problem solving, knowledge, and attention and engagement. A key concept to investigating effects of learning strategies is understanding students' individual differences in learning, the environment in which learning occurs, and the teachers' role in the learning process, which we believe includes behaviors and innovation. In reviewing variables, they are all applicable within agricultural education: fixation (consistent or stable eye movement; temporal, spatial, and count), saccade (eye movement between fixations), or combination of the two (Lai et al., 2013).

Within agricultural communication, we believe the primary audience is consumers. The term consumers is used broadly as even agricultural producers and agricultural science (broadly defined) students and professionals are consumers of information. We recognize other audience bases may be appropriate in agricultural communication research, but consumers' perceptions, attitudes, and behaviors are the most likely to be investigated using eye-tracking technologies. Consumers provide scientists with two primary areas for investigation—behavior change and effects of communication modes (attitudes, recall and accuracy, and attention)—within formal and informal environments. Additionally, in reference to variables, fixation (consistent or stable eye movement; temporal, spatial, and count), saccade (eye movement between fixations), or combination of the two (Lai et al., 2013) have application in agricultural communication.

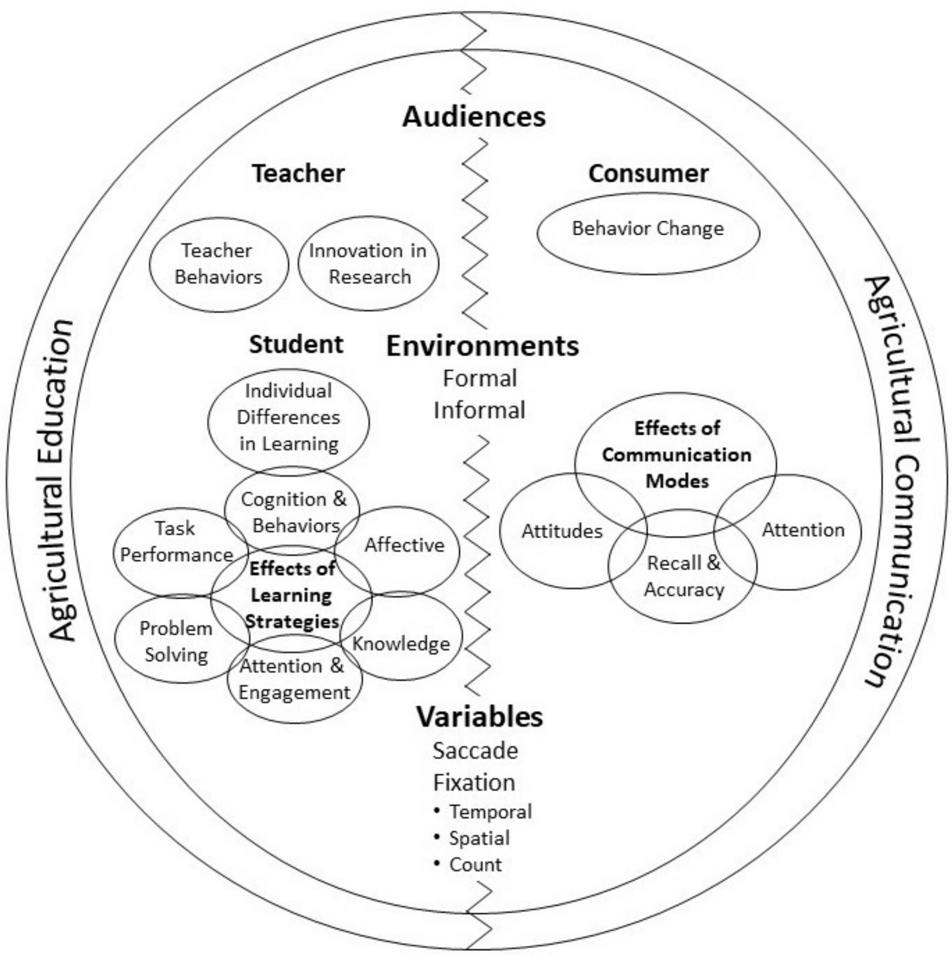

Figure 1. Conceptual framework identifying the audiences, concepts, environments, and variables that should guide eye-tracking technologies research within agricultural education and communication.

Conclusions and Recommendations

Conclusion 1: Lack of agricultural education and communication studies using eye-tracking methods cited in Web of Science Social Sciences Citation Index.

When searching the Web of Science Social Sciences Citation Index (SSCI), we did not find eye-tracking studies within the context of agricultural education, communication, leadership, or extension, and not one article met the criteria of this search focused on agriculture. However, we did find eye-tracking studies conducted in the context of education and communication as broader disciplines. We recognize some may see using the SSCI database as a limitation to our study. However, the SSCI database is comprised of top journals across 55 disciplines of social science, many of which are high-indexed, prominent journals within each discipline. Therefore, one could argue searching the SSCI provided us the most prominent articles within the broader disciplines of education and communication. If we are to begin conducting research that measures variables related to eye-tracking technologies, then limiting our search to the SSCI database is important for studies like this one. Perhaps, citing the articles inclusive in this study and conducting rigorous research related to agricultural education and communication could open the door for scientists in our profession to publish high impact studies in “the most influential scientific” journals (Clarivate Analytics, 2018, para. 1).

Thus, we, agricultural educators and communicators, should discuss the potential uses of eye-tracking technologies to improve the research within the disciplines. The conceptual model we developed as part of this study should help guide conversations within the profession and help us identify variables of interest in the current research paradigms that could align with eye-tracking technologies. Publications, reviews, and professional development opportunities should highlight and clarify the methods, equipment, and costs of conducting eye-tracking technologies. Perhaps, we could even invite an expert in eye-tracking technologies to conduct a professional development workshop at a national research meeting.

Conclusion 2: Eye-tracking technology provides variables to support a multivariate approach in agricultural education and communication.

Stevens (2009) suggested an effective treatment will impact an individual in more than one way, and a multivariate approach to behavioral research provides a more valid and realistic research perspective. As depicted in Figure 1, eye-tracking provides a reliable measure for a number of constructs that could be valuable additions to the dependent variables of interest. This review of educational research yielded a very broad array of dependent variables of interest—task performance, attention, engagement, knowledge gained, cognition, problem-solving, and affective state of learners. Many of these variables are often noted in agricultural education studies, and eye-tracking technologies provide us more rigorous ways to investigate such dependent variables. In agricultural communication, this review highlighted the ability of eye-tracking to monitor consumer behaviors as they interact with media. Though much can be learned through the responses of subjects in communications research, the ability to add monitored behavior could provide valuable information in communication science.

Thus, scientists studying the agricultural behavioral sciences should embrace technologies, like eye tracking, to move toward a more multivariate approach of research. As scientists use eye-tracking technologies in various ways, more innovative ways to capture a broader range of variables will become apparent.

Conclusion 3: Eye-tracking equipment is expensive, limiting diffusion in some settings.

Many of the studies in this literature review noted expensive software, hardware, and equipment were limiting factors. Most often, scientists conducted many of the studies in this review in professional settings where resources were more abundant than in a public school or university setting. Often noted, scientists acquired the eye-tracking software and hardware through public and private grants that established a *center* within the organization conducting the research. Thus, interested multi-state parties should explore external funding opportunities to secure the eye-tracking software and hardware to establish a number of *centers* that could support research teams in agricultural behavioral sciences as they use eye-tracking as a method of measurement. This multi-state approach could provide the broadest impact with the least amount of resources and develop consistency in how eye-tracking technologies are best used in the profession.

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