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NEUROECONOMIC STUDIES IN AGRICULTURE AND FOOD ECONOMICS: A SYSTEMATIC REVIEW OF LITERATURE

Key words: neuroeconomics, agriculture, food economics, electroencephalogram, Eye Tracker

ABSTRACT. The objective of the study is to gather studies related to neural correlates that are used in agriculture and food economics. We classified and codified those studies to describe all of the contributions and to present the future prospects of neuroeconomics in the field of agriculture and food economics. A systematic literature review was carried out for this study to consolidate all of the relevant studies in one place. With the use of IEEE Xplore, Wiley Online Library, Taylor & Francis, Elsevier, Scopus and Sage, 190 records were identified and after a full text examination, 18 articles were selected for final review. Three major thematic areas viz: focus, method and field of study were identified and sub-classified into further classifications. In this systematic review, there were substantial evidence of the use of neuro tools such as the Eye Tracker (ET) and the electroencephalogram (EEG) in the field of agriculture and food economics. However, their application is still rare, creating significant opportunities for further research development in this direction.

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INTRODUCTION

Neuroeconomics is a relatively new and an interdisciplinary area that combines the elements of economics, psychology, neuroscience and computational science [Riccardi et al. 2015]. The advent of behavioural economics can be traced back to the later part of the 17th century by Adam Smith in his work "The theory of moral sentiments'" which used many psychological concepts that could explain the understanding of an interesting and complex human brain. Later in the 20th century, behavioural economics saw many developments that explained the respective effects of cognitive, emotional, psychological, and social factors in an individual's decision-making abilities and these very developments deviated from the explanations offered by standard economic theories. Nuroeconomics utilises various tools to test the biological basis of economic behaviour. Eye Trackers (ET) have been used to track visual attention, fixations, saccades and pupil dilation in previous studies and in a much sophisticated manner in tracking mutual interactions in the course of playing economic games [Kee et al. 2021]. Galvanic skin response (GSR) tracks the emotional arousal that arises from the activation of sweat glands in the skin. GSR is also called as galvanic skin activity (EDA) or galvanic skin conductance (SC). When an emotional stimuli is sent, it triggers the sweat glands and resultant emotional excitement is reflected and quantified in GSR [Xu et al. 2023]. An electroencephalogram (EEG) measures the electrical potential on the scalp generated by neural responses from the brain. The main advantage of the EEG (over the other tools aforementioned) is its temporal resolution in milliseconds or even below that [Kenning et al. 2005].

Magnetoencephalogram (MEG) is a neuroimaging technique that tracks the changes in magnetic fields induced by brain activity. Similarly, positron emission tomography (PET), functional magnetic resonance imaging (fMRI) and functional near infrared spectroscopy (fNIRS) are some of the advanced tools that track human behaviour and interactions during vital decision making in day- to-day economic activities. Agriculture and food economics have only recently started exploring these tools and methods to go beyond the traditional methods of cognitive questionnaire and to seek a deeper understanding of the decision making process. Although this area is new and fast paced, a few notable studies have been conducted in order to introduce brain dynamics into the picture. This paper has tried to curate such studies to track the evolution of the use of neuro tools in agriculture and food economics. It also talks about the use of Eye Tracker on the similar lines of marketing studies which can also guide Agricultural Marketing towards exploring consumer behaviour (or producer behaviour).

The objective of the study is to gather studies related to neural correlates that are used in agriculture and food economics. We classified and codified those studies to describe all

of the contributions and to present the future prospects of neuroeconomics in the field of agriculture and food economics. An important research question that arises is which are the priority areas of agriculture and food economics as identified in the literature; wherein Neuroeconomics is applied?

MATERIAL AND RESEARCH METHODOLOGY

A systematic literature review was carried out for this study to consolidate all of the relevant studies in one place. Though neuroeconomics in general economics has been given substantial emphasis since its inception, but the application of neural correlates in agriculture and food economics is relatively new. The novelty of neural pathways' studies in agriculture warrants a heightened importance to collect, curate and store literature in one place. This paper is aimed at studying such important literatures and their contributions in the field and how such important observations could serve as potential stepping stones for future studies in this area [Junior, Godinho 2010], has suggested the following steps to conduct a literature review:

Step 1. Review literature regarding application of neuroeconomics in agriculture and food economics.

Step 2. Create a classification system to separate the different domains of study.

Step 3. Apply classification structure to curate what is already known regarding the study.

Step 4. Organise reviews based on the classified literature review.

Step 5. Analyse the classified review and state the future prospects of the study.

INCLUSION AND EXCLUSION CRITERIA

The study was concentrated on the application of neuroeconomics in agriculture and food economics and in order to serve the stated purpose, a few inclusion and exclusion criteria were applied. All studies originally performed inside the laboratory and/or a field set up and their related literature published in the English language have been included herewith. We took into consideration of EEG and Eye Tracker studies here due to the availability of their research in agriculture and food economics and the focus of their methodology that can guide the future research on the similar lines. Studies related to fMRI (functional magnetic resonance imaging) and fNIRS (functional near infrared spectroscopy) have been excluded as there are no studies that have been found directly in agriculture and food economics yet.

REVIEW LITERATURE REGARDING APPLICATION OF NEUROECONOMICS IN AGRICULTURE AND FOOD ECONOMICS

Database search by key words. The study identified all the cross-sectional and longitudinal studies published after 2015. The search was mainly focused on keywords, abstracts and article titles. The keywords included terms like "neuroeconomics", "neural correlates in agri*", "electroencephalography in agri* economics", "electroencephalography in agri*", "eye tracker in agri* economics", "neural pathways in food economics". other related keywords like "behavioural economics", "decision neuroscience", "neurophysiology", "brain dynamics" were also searched in relevant databases.

Database search by journals. An exhaustive search of all the published research papers was done. A systematic search in the journals like IEEE Xplore, Wiley Online Library, Taylor & Francis, Elsevier, Scopus and Sage was performed. All the research not relevant to the study was excluded. since neuroeconomics transcends different subjects such as economics, psychology and neuroscience, PubMed has also been helpful in directing some studies. Different sources have been consulted in searching and filtering relevant articles.

Study selection process. Initially 190 records were identified through different databases and after careful screening, exclusion as well as a full text examination, 18 articles were selected for final review (Table 1). All of these studies directly relate to neuroeconomic studies in agriculture and food economics. The flow chart of study selection process is shown in Figure 1.

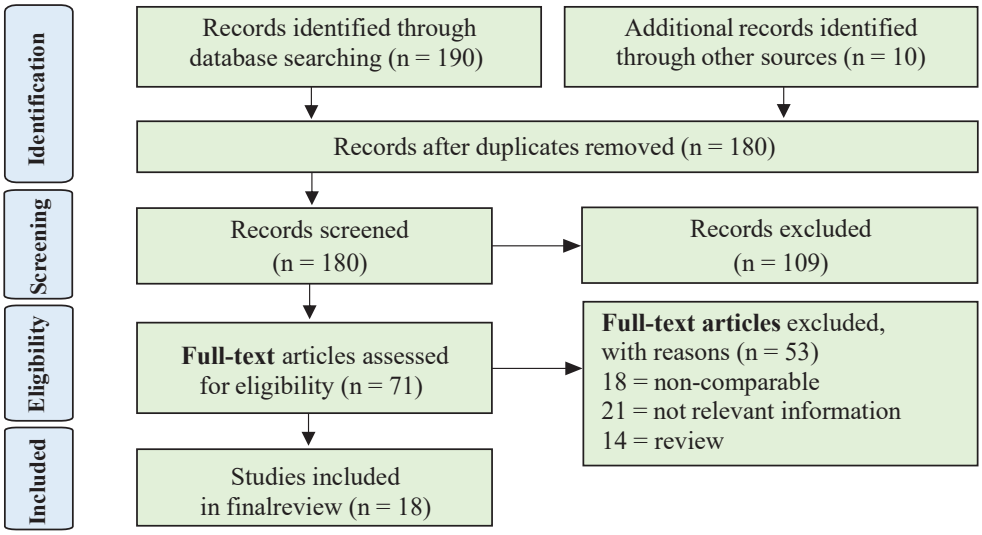

Figure 1. Study selection process
Source: [Moher et al. 2009]

Table 1. Selected characteristics of 18 studies included in the classification

Source	Theoretical background	Problem	Method used	Results
Kovács et. al. [2016]	Behavioural decision theory	Consumer perception of food	Eye Tracker	Eye Trackers can be used jointly with other tools e.g. face readers (which analyse the facial expressions of the participants and identify basic emotions such as happiness, anger, etc.) or electroencephalograph (which records the electrical activity of the brain)
Rihn et. al. [2016]	Behavioural decision theory, preference decisions of consumers, willingness to pay	Consumer preference decisions for organic production methods and origin promotions	Eye Tracker	Consumers prefer certified organic and organically produced plants over conventionally produced plants
Gidlöf et. al. [2017]	Eye movement theory	Influence of consumer preferences and properties of the supermarket shelf on choice	Eye Tracker	Consumers appear to take advantage of visual saliency in their decision making, using their knowledge about products' appearance to guide their visual attention towards those that fit their preferences. When it comes to actual purchases, however, visual attention was by far the most important predictor, even after controlling for all other internal and external factors
Aprilianty et. al. [2018]	Behavioural decision theory, trust, perceived value	Effect of buyer's role in achieving collaborative business relationship in the agriculture business	EEG	Most farmers have the highest interest response to the perceived value, and engagement response leading to trust, towards farmers groups, while exhibiting the lowest interest and engagement responses to cooperatives
Meyerding et. al. [2018]	Preference decisions of consumers	Influence of organic label on visual attention and choice	Eye Tracker	Consumers who gain greater utilities from specific attributes of a good also attend to them visually to a greater extent

Table 1. Cont.

Source	Theoretical background	Problem	Method used	Results
Panfilov et. al. [2018]	Behavioural decision theory	Gaze distribution on the real-time visual information for the remote supervision of an Autonomous Agricultural machine	Eye Tracker	Live video is poorly suitable for detection of agricultural sprayer problems and participant performance was poorer during the trials with live video. Participant attention gradually shifted to the indicators screen from 50/50 at the beginning to 70/30 at the end of the experiment
Takahashi et. al. [2018]	Behavioural decision theory, preference decisions of consumers	Consumer motivation on certified forest coffee purchase	Eye Tracker	Information on the certification program or concern toward environmental issues does not significantly affect consumers' purchasing behavior for certified forest coffee
Schröter et. al. [2019]	Behavioural decision theory	Neural corelates of perception of information about aquaponics	Eye Tracker	Allocation of visual attention is linked to the specific information content and to the evaluation of naturalness of aquaponics production. A relationship between gaze behaviour evaluation of aquaponics production indicated that the openness towards the production method seemed to be related to its perceived naturalness
Georgakarakou et. al. [2020]	Eye movement theory, Eco-labelling	Influence of packaging on buying behaviour	Eye Tracker	The findings indicate that people are more interested in the brand name when buying feta cheese and olive oil and seem not to care about the shape nor the colour of the package
Rödiger et. al. [2020]	Behavioural decision theory, willingness to pay	Visual attention to price during organic and conventional food purchase	Eye Tracker	There was no difference between regular organic, occasional organic and conventional consumers in the amount of visual attention allocated to prices of organic food; however, of the time that participants spent looking at organic alternatives, conventional consumers gazed significantly longer at prices of organic food than regular and occasional organic consumers

Table 1. Cont.

Source	Theoretical background	Problem	Method used	Results
Stanton et. al. [2020]	The Limited Capacity Model of Mediated Moderated Message Processing (LC4MP) theory	Message dissemination in Agricultural Communications Research	Eye Tracker	This study has implications within the processing of value-oriented messages, as they elicit more attention and thus, provide a route for information processing and attitude development
Kee et. al. [2021]	Behavioural decision theory	Does eye-tracking have an effect on economic behaviour?	Eye Tracker, EEG	Using eye-tracking equipment does not affect individual behaviour in economic decision making for seven out of eight popular economic games. Participants, on average, behaved the same in both eye-tracking and no eye-tracking conditions, particularly after implementing standard procedures, such as controlling for the number of participants per session or clustering standard errors at the session level in the double auction
Schukat et. al. [2021]	Behavioural decision theory	What links neuroscience to agricultural economics? A review of neuroscientific methods literature in agricultural economic research and marketing	Eye Tracker, EEG	The key findings show three categories in which agricultural economic research issues have been considered. These include brands and preferences, nutritional as well as purchasing behaviour and advertising and marketing
Zeng et. al. [2021]	Behavioural decision theory	Neural emotional response to the vegetation density (VD) and integrated sound environment (ISE) in a green space	EEG	This study found that a higher level of VD was more likely to result in excitatory neural emotions. The main effect analysis showed that the main effect of the ISE was significant. Also, the focused emotional expressions can be more easily realized in a space with continuous vegetation

Table 1. Cont.

Source	Theoretical background	Problem	Method used	Results
Kumar et. al. [2022]	Behavioural response, response to stressor	Role of EEG in preslaughter management	EEG	Electroencephalography is a sensitive, efficient, and cutting edge technique for measuring stress related to *noxious stimuli*. The stress leukogram, muscle enzymes, and hormonal blood markers are highly related to the EEG spectrum between the neck cut and unconsciousness in response to various painful stimuli
Liang [2022]	Behavioural decision theory	Neurocognitive correlates of problem solving skills for various level of creativity	EEG	The results indicated that numeric problem solving activated the frontoparietal network and was associated with a high level of self-generated thought. The function of evaluating creativity was inhibited in the HC (High Creativity) group, and the participants engaged in divergent semantic processing during the numeric task
Palma [2022]	Behavioural decision theory	Neuroeconomics: An overview and applications to agricultural and food economics	Eye Tracker, EEG	The agricultural economics field is uniquely positioned to integrate these devices into traditional methods to study food choice to enhance research and outreach programs and improve food policy analysis
Zhang et. al. [2022]	Eye movement theory	Influence of cognitive factors on visual behaviour and satisfaction preference for forest recreation space	Eye Tracker	(1) Places with more frequent eye movements have relatively lower satisfaction preferences; (2) The spatial perception factors affect participants' visual behaviour, and satisfaction preference is different based on many indicators (WCB, WSO, WSN, SSH, etc.) in forest recreation space; (3) The professional background education affects the participants' visual-behaviour evaluation of the recreational landscape space and also affects the participants' focus on the landscape preference

Source: own elaboration based on the literature review

CREATE A CLASSIFICATION SYSTEM TO SEPARATE DIFFERENT DOMAINS OF STUDY

A classification system was created to separate screened studies into thematic areas as shown in Table 2. Three major thematic areas were identified, and sub-classified into further divisions. For this study, three major thematic areas were identified viz: focus, method and field of study. It illustrates the fact that the first classification was in terms of focus of study that was further detailed into neural response of the brain through electroencephalography (EEG) coded as "A", gaze directions and visual attention through Eye Tracker (ET) coded as "B" and reviews on literature coded as "C". The second thematic area was related to method that followed electroencephalography (EEG) coded as "A" and Eye Tracker (ET) coded as "B". Last thematic area was named as field of study and divided into agriculture coded as "A", food economics coded as "B" and others (rural development, veterinary etc.) coded as "C".

Table 2. Classification framework and coding

Classification	Meaning	Codes for alternatives
1	Focus	A – Neural response of brain through electroencephalography (EEG) B – Gaze directions and visual attention through Eye Tracker C – Reviews on literature
2	Method	A – Electroencephalography (EEG)
		B – Eye Tracker (ET)
3	Field of study	A – Agriculture
		B – Food economics
		C – others (rural development, veterinary etc.)

Source: own study

RESULT AND DISCUSSION

This study was carried out with the help of past literature that mainly focused on neuroeconomic tools such as EEG and Eye tracker in the field of agriculture and food economics. Eye Tracker is generally popular and is mostly used in consumer studies, marketing and business studies to measure visual attention through gaze behaviour [Gheorghe et al. 2023]. But the use of EEG, GSR has been limited in the same field. Chaoyun Liang [2022] in his study used EEG to measure neurocognitive correlates of

problem solving skills for various level of creativity in the field of agricultural extension. Moreover, there have been several studies which use EEG in veterinary studies.

Figure 2 tells the frequency distribution of focus and only 7 studies have measured neural response of the brain through electroencephalography (EEG) while a majority of studies i.e. 14 studies used Eye Tracker and a few studies dealt with the review of literature. The review of literature explained the physiology of the brain and the eye, a detailed description of the research framework of EEG and Eye Tracker and their methodology. There exist many studies in marketing and business that use Eye Tracker but only a few studies in agriculture have been conducted which makes it far a significant research gap still left to explore.

Figure 3 depicts the Frequency distribution for method and is divided into EEG and Eye Tracker. Majority of the studies have been carried out with the help of Eye Tracker and a few studies have utilised EEG. There are many studies in economics that have studied strategic decision making on multiple levels [Pammi, Miyapuram 2011]. Agriculture economics can be linked to neuroscience just like the economics-neuroscience interlink. However, the agriculture & food economics-neuroscience relationship has wide research gap that still needs to be filled. This has been further indicated in Table 3 titled „Evidence for current research" that the exploration of brain in the field of agriculture and food economics is much needed.

Figure 4 illustrates the frequency distribution of field of study. Majority of the studies have been done in agriculture followed by food economics and other areas like rural development, veterinary studies etc. As stated above, there has been a rich scientific account of eye tracking research in the neuroscience community. One of the key consumer behavioural patterns observed herein is that while buying certain products, the consumer tends to select them on the basis of the packaging, text, information and images printed over the packages. Eye Tracker tracks the eye movement matrix viz: total fixation count, fixation count within an area of interest (AOI), fixation duration, dwell count, fixation spatial density etc, and draws a heat map based on these matrix which conclusively describes gaze behaviour and thus the final selection of the products [Kovács et al. 2016]. Alicia Rihn et al. [2016] analysed the consumer purchase likelihood and visual attention paid to organic production methods and origin extrinsic cues on aesthetic and fruit-producing plants.

They found out that the additional use of the organic production method triggered a positive purchase response. Kerstin Gidlöf [2017] while studying the "Influence of consumer preferences and properties of the supermarket shelf on choice" found out that visual attention is by far the most important predictor of consumer choice even after controlling all the internal and external factors possible. Consistent with the previous study done by Alicia Rihn et al. [2016] on organic products, Stephan Meyerding and Nicolas Merz [2018] in their study found out that consumers are most likely to gaze at

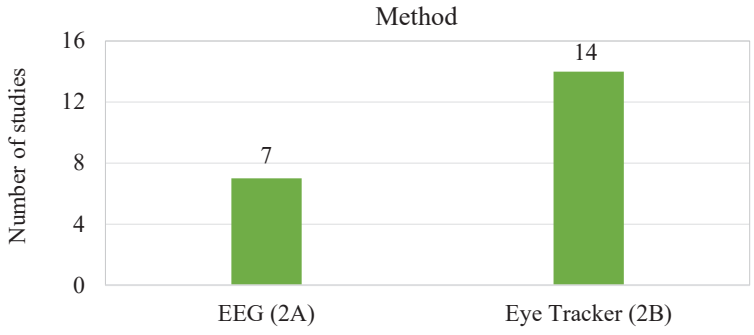

Figure 2. Frequency distribution for focus
Source: own elaboration based on the literature review

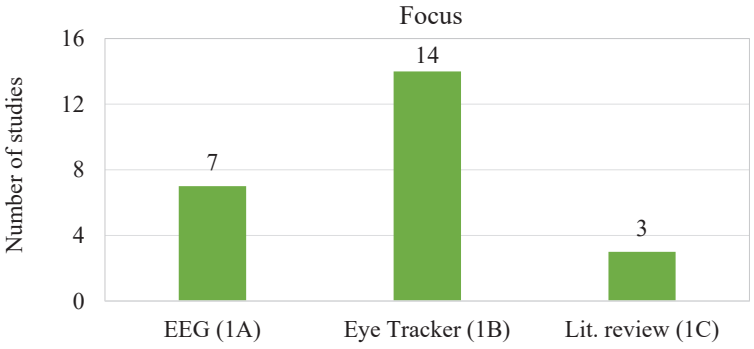

Figure 3. Frequency distribution for method
Source: own elaboration based on the literature review

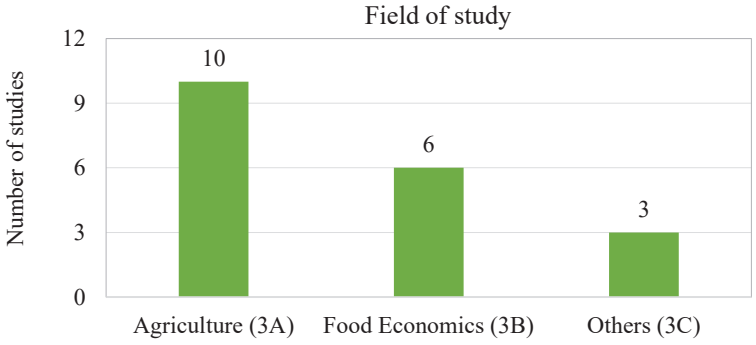

Figure 4. Frequency distribution for field of study
Source: own elaboration based on the literature review

a certain attribute in a product for a longer period of time when they intend to buy and extract greater utility out of such a product.In a different study done by Ryom Takahashi et al. [2018] who analysed consumer motivation displayed on the purchase of certified forest coffee reported that, there is no significant impact of the texts addressing the environmental concerns on the buying behaviour. But those consumers who possessed prior experience of using forest coffee products showed positive purchase behaviour. Iris Schröter and Marcus Mergenthaler [2019] studied the Neural correlates of perception of information about aquaponics thereby explaining the relationship between gaze behaviour of aquaponics' production. It revealed that the openness to select a particular production method is related to its perceived naturalness. Chrisanthi Georgakarakou et al. [2020] while studying eco-labelling and the influence of packaging on buying behaviour revealed that consumers are interested in a brand name rather than in the shape or the colour of experimental products viz: feta cheese and olive oil. Further, Manika Rödiger and Ulrich Hamm [2020] studied the visual attention to price while buying conventional and organic food products. They found out that there is no significant difference in visual attention excercised on conventional and organic product prices but the optical fixation was found to be longer on organic product prices. Caitlin Anne Stanton and Laura Morgan Fischer [2020] studied the message dissemination in Agricultural Communications Research and found out that value oriented messages are disseminated positively for attitude development. Zhi Zhang et al. [2022] while analysing the "Influence of cognitive factors on visual behaviour and satisfaction preference for forest recreation space" found out that places with frequent eye movement have relatively lower satisfaction preferences and that having a professional educational background affects the evaluation of satisfaction of recreational landscape.

Electroencephalogram (EEG) is rather new in the area of agriculture and food economics but it contributes significantly towards tracking the neural correlates of various economic behaviours and strategic thinking of individuals during decision making. Fitri Aprilianty et al. [2018] in a study on trust and perceived value while studying "Effect of buyer's role in achieving collaborative business relationship in the agriculture business" found out that the most participants (86%) had the highest interest response on perceived value in relation to the farmers group and the lowest interest in co-operatives (41%). For female participants, the amplitude value in the left hemisphere is higher than that in the right hemisphere whether in the parietal lobe (Pz), frontal lobe (AF3-F4), or temporal lobe (T7-T8). Further, Chengcheng Zeng et al. [2021] in his study on "Neural emotional response to the vegetation density (VD) and integrated sound environment (ISE) in a green space" studied that a higher level of vegetation density was more likely to result in excitatory neural emotions and continuous vegetation produces focused emotional expression. Chaoyun Liang [2022] tried to delve into the problem solving behaviour by agricultural extension students with various levels of creativity. He interestingly found

out that those problems that are associated with numbers activate frontoparietal network and are indicators of high self-generated thought. The results indicated that numerical problem solving activated the frontoparietal network and were associated with a high level of self-generated thought. In veterinary science, the response to stressors was studied with a neurocognitive lens. Pavan Kumar et al. [2022] found out how EEG is the accurate predictor of unconsciousness in response to noxious and painful stimuli.

DISCUSSION AND CONCLUSIONS

In this systematic review, there were substantial evidence of the use of neuro tools such as the Eye Tracker (ET) and the electroencephalogram (EEG) in the field of agriculture and food economics. Behavioural economics has claimed its due position in the late eighties and therefore there have been many studies in the past that have included humans as a subject used in testing various behavioural patterns. Neuroeconomics as a branch of research based study has emerged relative (compared to classical economics) recently and hence warrants more research iterations to obtain further insights.

Currently in neuroeconomics, based on the Table 3 there exists gaps not only in the disciplines researched but there are also geographical disruptions in that, much of the important studies that have been and continue to be carried out are restricted to clusters around the world. Therefore, firstly there is a need to narrow these gaps by increasingly filling them with relevant studies undertaken in areas that can fill these gaps. These findings conclude the evidence of use of behavioural parameter measures in agriculture and food economics. Range of studies has contributed significantly towards the neuroscience mainly from Agricultural students' creativity estimates to veterinary animal stress responses whilst also taking into account the consumers' behavioural decision-making patterns and strategic thinking based on trust, willingness to pay and perception levels. This study has also highlighted the need for developing an idea centered around making more studies in the analysed field.

This paper suggests that future scholars can contribute significantly to the field of agriculture and food economics. More studies are required that focus on the uses of neuro tools in agricultural economics and related fields. There have been many studies already conducted and continue to be furthered in the field of consumer science, business and marketing but relatively only a few such studies have been carried out in agriculture. Farmers/rural areas inhabitants in general make for a good case study for analysing several cognitive estimates related to trust, perception, willingness to purchase, purchase likelihood etc. Neuro tools are expensive, and their acquisition cost forms the biggest hindrance in the way of carrying out these studies. Under such circumstances, support from organisations arriving by way of project initiatives, grants and funds shall pave the way for and take us far in this endeavour.

Table 3. Evidence for current research project

Author	Focus			Method		Field of study		
	A (EEG)	B (ET)	C (Lit. review)	A (EEG)	B (ET)	A (Agri.)	B (Food Eco.)	C (Others)
Kovács et al. [2016]		+			+		+	
Rihn et al. [2016]		+			+		+	
Gidlöf et al. [2017]		+			+		+	
Aprilianty et al. [2018]	+			+		+		
Meyerding et al. [2018]		+			+	+		
Panfilov et al. [2018]		+			+	+		
Takahashi et al. [2018]		+			+		+	
Schröter et al. [2019]		+			+	+		
Georgakarakou et al. [2020]		+			+		+	
Rödiger et al. [2020]		+			+		+	
Stanton et al. [2020]		+			+	+		
Kee et al. [2021]	+	+	+	+	+	+		
Schukat et al. [2021]	+	+	+	+	+	+		+
Zeng et al. [2021]	+			+		+		
Kumar et al. [2022]	+			+				+
Liang [2022]	+			+		+		
Palma [2022]	+	+	+	+	+	+		
Zhang et al. [2022]		+			+			+

+ represents the field where researches have been conducted and blank spaces are the areas that needs to be investigated and are termed as research gaps

Source: own elaboration based on the literature review

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BADANIA NEUROEKONOMICZNE W ROLNICTWIE I SEKTORZE ROLNO-SPOŻYWCZYM: SYSTEMATYCZNY PRZEGLĄD LITERATURY

Słowa kluczowe: neuroekonomia, rolnictwo, ekonomia rolna, elektroencefalogram, Eye Tracker

ABSTRAKT. Głównym celem artykułu jest przedstawienie przeglądu literatury na temat neuronalnych korelatów decyzji podejmowanych w sektorze rolno-spożywczym. Dokonano klasyfikacji i syntetycznego opisu zebranych badań i przedstawiono perspektywy rozwoju neuroekonomii w analizach z zakresu ekonomii rolnej. Systematycznym przeglądem literatury objęto wszystkie artykuły zawarte w IEEE Xplore, Wiley Online Library, Taylor & Francis, Elsevier, Scopus and Sage. Początkowo zidentyfikowano 190 rekordów, z których po dokładnej weryfikacji pełnych tekstów wybrano 18 artykułów do dalszej analizy. Sklasyfikowano artykuły względem trzech głównych obszarów tematycznych podejmowanych w analizowanych pracach, tj. cel, metoda i obszar badawczy, które zostały poddane dalszym klasyfikacjom. Badania wykazały wykorzystanie narzędzi neuroekonomicznych, takich jak Eye Tracker (ET) i elektroencefalogram (EEG) w badaniach z zakresu ekonomii rolnej. Ich zastosowanie jest ciągle jednak rzadkie, co stwarza duże możliwości rozwoju badań naukowych w tym kierunku.

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