World Journal of Neuroscience, 2023, 13, 67-89
https://www.scirp.org/journal/wjns
ISSN Online: 2162-2019
ISSN Print: 2162-2000

Assessment of the Neurological Activation in Law Enforcement under High Threat Situations: A Fuzzy Logic Approach

Daniel Fonseca[1*], Isaac Heim[1], Rick Houser[2], Ryan Cook[2], John O'Donnell[1]

[1]Department of Mechanical Engineering, The University of Alabama, Tuscaloosa, USA
[2]Department of Educational Studies in Psychology, Research Methodology, and Counseling, The University of Alabama, Tuscaloosa, USA

Email: *dfonseca@ua.edu

How to cite this paper: Fonseca, D., Heim, I., Houser, R., Cook, R. and O'Donnell, J. (2023) Assessment of the Neurological Activation in Law Enforcement under High Threat Situations: A Fuzzy Logic Approach. *World Journal of Neuroscience*, **13**, 67-89.
https://doi.org/10.4236/wjns.2023.131005

Received: August 17, 2022
Accepted: February 24, 2023
Published: February 27, 2023

Abstract

This paper discusses a law enforcement officer (LEO) study that involved expert and novice police deputies from a small-sized city located in the Southern U.S. A virtual reality range was utilized to simulate high threat scenarios that require split second decisions on the use of deadly force. A fuzzy-logic based controller was constructed to analyze electroencephalogram (EEG) data collected from the participants. The fuzzy controller made use of several functions associated with the different regions of the brain to correlate Brodmann areas to multiple outputs. Electromagnetic Tomography (*i.e.* LORETA) was used to identify where the signals from the surface electrodes originated within the brain through a process called source localization. Once the sources of the EEG signals were located, they were associated with corresponding Brodmann areas. The fuzzy controller then provided insights on the subjects' exhibited neural activation behavior indicative of vision, memory, shape/distance, hearing/sound, and theory of mind. Comparing and contrasting experienced and novice officers allowed for a greater understanding of the neurological processes present in police deputies when dealing with high threat situations.

Keywords

Neurological Activation, EEG, Fuzzy Controller, Brain Electromagnetic Tomography

1. Problem Background

The job of a law enforcement officer (LEO) is notably dangerous, as police-citizen encounters have the potential to turn to deadly violence. Encounters with the public are extremely dynamic, and a situation may shift from compliance of the citizen into an assaultive nature in a matter of seconds. A key goal of research on LEO decision-making is to explore factors that can de-escalate or prevent situations ending in death for everyone involved. Law enforcement is best achieved when de-escalation efforts are utilized, so the encounter does not reach the use of deadly force [1].

A law enforcement officer's decision to shoot or not to shoot in high threat environments is complex. There are many factors to consider, such as physical skills (act of firing a weapon with repetitive practice), physiological responses (highly stressed versus in control of emotions), individual perceptions that influence decisions (e.g. race), cognitive decision-making (anticipating the outcomes), and ethical decision-making (recognizing ethical issues). The underlying neuro processes in a decision to shoot or not to shoot in a high threat environment is not well understood. Given the significant impact of these decisions in high threat environment it is critical to begin investigating [2]. Another factor in the decision to shoot or not shoot is theory of mind (ToM). Theory of mind is attributed to the capacity to understand the metal states of others. This includes intentions, motivations, and beliefs. This realization drives the behavior of the individual interpreting the situation [3].

Research has been conducted into the neurological processes of law enforcement officers' decisions to shoot or not to shoot in high threat environments. In one such study, experts have shown differences in power, brain wave power, and power in different brain regions. Brain waves have been clearly differentiated by frequency. There are five different waves that have been identified as delta, theta, alpha, beta and gamma. Delta waves range from 1 to 4 Hz; theta waves contain the range of 4 to 7 Hz; alpha waves include 8 to 12 Hz; and beta waves are 13 - 30 Hz. Haufler, Spalding, Santa Maria, and Hatfield (2000) found that experts had an increased alpha power (10 - 11 Hz) in the left prefrontal cortex while aiming when compared with novices. Also, experienced officers had higher frequency in the theta bands (6 - 7 Hz) in both left and right prefrontal cortex during aiming [2].

Law enforcement officers may have little time to assess high threat situations in complex environments, and in that time, they must decide to shoot or not to shoot. An important, albeit often-neglected, aspect of this decision-making process is what happens after the threat has been neutralized. Following high threat situations that are ambiguous and challenging, individuals engage in a period of cognitive reflection [4]. Since there is no obvious solution, this reflection period can further the knowledge and understanding of the law enforcement officer's brains process [5]. While the reflection period of high threat situations of law enforcement officers has yet to be investigated, there is empirical evidence from the medical profession that engaging in reflection is connected to improving decision-making. Medical doctors are much like law enforcement officers. They rely on previous training and expertise to make quick decisions, and decode difficult situations using automatic processes [6]. These automatic processes are effective in commonly occurring cases. Although, in complex cases that do not follow this mold, these processes are relatively ineffective as the doctors' collection of existing knowledge may not be useful to the current situation [6] [7]. Berner and Garber (2008) reviewed the accuracy of doctors' medical diagnoses and concluded that the doctors' inability to reflect on situations was connected to missed or wrong diagnosis [6]. Conversely, their ability to reflect on challenging cases is associated with improved diagnostic accuracy and better clinical reasoning [7] [8].

Studies on expert marksmen have utilized the reflection period in order to learn more about the decision-making process that occurs prior to firing a weapon [9]. The heartrate and skin conductance of novice and expert marksmen before, during, and after discharging pistols is compared as well. These researchers focused on comparing the best and worst shots of both groups. In doing so, the researchers found evidence of two physiological processes of which are arousal and vigilance. Arousal is defined as anxiety that occurs during pressure situations, while vigilance is defined as attention concentrated on a particular stimulus. The study found that experts' arousal level had little to no variation before, during, and after the shot, while the novice marksmen's demonstrated arousal throughout the experiment. The more vigilance displayed by the experts prior to the shot correlated with accuracy. Additionally, while the experts were more accurate, their vigilance decreased at a slower rate than when they missed. Tremayne and Barry (2001) interpreted this as the expert marksmen were more "locked in" prior to the shot are more reflective over a longer period of time after shooting [9].

Law enforcement officers' reflection and insight analysis in high threat decisions is still not prevalent. Similar findings from the medical profession and recreational shooting, provide evidence that reflection periods are critical for improved decision-making. There have been a few studies using physiological assessments such as EEG to understand the reflection and insight [10] [11] [12] [13]. Researchers have found that alpha, theta and gamma brain waves activity correlated with certain brain regions during periods of reflection. Kounious, *et al.*, [11] observed an increase in anterior cingulate cortex (midline) activity when engaged in insight orientated tasks and specifically prior to engaging in such tasks. They concluded that the increase activity may be associated with managing relevant thoughts and suppressing irrelevant thoughts to the task.

There are more factors that impact law enforcement officers' decision-making. These include the context of the situation and racial attitudes [14]. During emotional circumstances, the amygdala has been noted to be active and in issues of race the amygdala response is heightened further [14]. Halliburton noted that the amygdala serves as a signal for detecting threats and, more importantly, the identification of those that can be trusted. Consequently, the biases and perceptions of race that officers have affect the decisions based on them which in turn impact their responses. This leads to officers potentially being hypervigilant when race is involved. Race influences significant amygdala activity which is location in the central part of the primitive limbic system. Determining trust is essential to survival which is why it is subject to this influence [14]. Understanding how to mitigate this "natural" responses, as well as, decisions making in high threat environments is important. Racial bias in shooting decisions may be explained by the effects of race on perception-based decision making [15] [16] [17]. Payne's (2001) study involved participants primed with either a white or black face before they were asked to decide if a visual object was a tool or gun. They discovered that during trials primed with a black face, participants were quicker at responding correctly to a gun and were also more likely to label a tool as a gun. Another part of the study presented pictures of black or white men holding tools or guns and participants were asked to decide whether to press a "shoot" button or a "no shoot" button based on if there was a gun or not [18].

Based on a diffusion model, Correll *et al.* [15] concluded that information on race made people more likely to misperceive a tool as a gun due to bias affecting ambiguous visual information. In the same shoot/no-shoot approach, it was found that the amygdala had increased functional connectivity with regions in the ventral visual processing stream which is known to be involved in visual object identification [16] [17]. Race information may influence the classification of tools and weapons because of the effect of amygdala activity on visual processing. These results establish a model in which it may be possible to expand the understanding of neural representation of race and how the information is incorporated into decisions within the brain. Research in recent years propose that the neural underpinnings of race, stereotyping, and prejudice and a number of brain regions have been consistently found to be activated during tasks involving race [19] [20]. These activated regions all include the amygdala. They are the anterior cingulate cortex (ACC), the dorsolateral prefrontal cortex (DLPFC), the fusiform face area (FFA), insula, orbital frontal cortex (OFC), and the anterior temporal lobe (ATL).

Computer simulations aid in understanding law enforcement officers' decisions in high threat situations. They have also been used to investigate the impact of race of the potential offender in making decisions to shoot or not to shoot. There is however a more natural method in virtual scenarios that can aid in assessing decisions to respond in high threat situations. High threat scenarios not only provide opportunities to understand the neural processes during the decision to shoot or not to shoot but also provide the opportunity to study the reflection period after the scenario is completed. These high threat simulations in the virtual firing ranges help to understand the neural and behavioral processes of law enforcement officers.

2. Description of the Study

The conducted research aimed to gain insights pertaining to the neural activity in officers while participating in simulated high threat situations. The study involved the use of Standardized Low-Resolution Brain Electromagnetic Tomography (sLORETA) to identify the neural generators for the high threat scenarios. These generators correspond to different functions of the brain and could then be used to understand the capabilities and focus of the officers.

2.1. Participants and Procedure

The officers that volunteered for this research included four male local-level LEOs from a small sized city (20,000 to 100,000) located in the Southern U.S. The participants averaged 5.75 years of experience with a standard deviation of 6.75 years. All the LEOs identified their race as white and had an average age of 33.5 years (SD = 11.96 years). In order to maintain participant confidentiality, other demographic information was excluded from the study. Participants completed 18 scenarios over three sessions (six scenarios per session), simulating high threat situations using a firearms training system. Each session lasted approximately an hour and included scenarios which had the intended outcome of the use of deadly force (*i.e.*, the participants firing their service weapon) and ones that did not have deadly force as the intended outcome (*i.e.*, participants should not fire their weapon during the scenario). In the situations that called for deadly force, the suspect directed a weapon at the officer or a bystander, thereby enabling the legal use of deadly force by the officer [21]. Scenarios were presented in random order. EEG data was collected for a 3-minute baseline prior to starting each session (participants sat in a chair in a comfortable position with their eyes closed). Participants were given a 2-minute break in between each scenario. All participants completed nine high stress scenarios; all participants completed the five of the same intended shoot scenarios. The remaining four scenarios were different between the participants.

2.2. High-Fidelity Training System

The study was performed at a police training facility equipped with a high-fidelity firearms training system virtual simulator developed by Meggitt Training System. The system is setup in a virtual shooting range, wherein the scenarios are projected onto a wall-size screen located on the far wall. The gun used by the participants was a real handgun (Glock 19) that had been modified to shoot infrared light when the trigger was pulled. In addition, the handgun was affixed with a carbon-dioxide cartridge to give the feel of a real gunshot with recoil when the gun was fired.

2.3. Video Scenarios

Each scenario was approximately one to two minutes long. These scenarios presented situations or activities that LEOs could experience during their everyday activities (e.g., DUI traffic stop, hostage situation, etc.). Scenarios analyzed in this study were ones that required the LEOs to utilize deadly force. Before each scenario began, the participants were provided with a brief description of each scenario, but the LEOs were not informed of the intended outcome. The participants did not receive any demographic information or mental health indicators of the suspects prior to the start of the scenario. These scenarios were presented in random order for each participant. An example of the setup is shown in **Figure 1**.

2.4. EEG Recording

EEG data was collected using a 64-channel mobile EEG amplifier called EEGO Sports [22]. This unit records data using EEG caps and electrodes connected to a mobile amplifier with the data saved to a high-performance Windows 8 tablet. This mobile EEG unit is manufactured for use on participants who move frequently (e.g., athletes) to record physiological and neurological data. Nineteen channels were focused on in this study. These channels aimed to target the neural processes of the subject while engaged in firing a weapon [23]. The reference electrode was CPz and the 19 channels utilized were Fp1, Fp2, F7, F3, Pz, F4, F8, T3, C3, Cz, C4, T4, T5, P3, Pz, P4, T7, T8, T6, TP7, TP8, O1 and O2. Data collection took place at a sampling rate of 500 Hz in an ambient temperature room. The measured impedances were all maintained below 20 kΩ.

2.4.1. Pre-Processing of EEG Data

EEG data was pre-processed in ***asalab*** software package [22] and EEGLAB toolbox for MATLAB [24]. The noise was processed with a 30 Hz lowpass filter. Data was then converted to a format compatible with EEGLAB for the remainder of analysis. As in prior studies, there was some participant movement involved [25]. Independent Component Analysis (ICA) was utilized [26] to remove artifacts (e.g., eye blinks, muscle movements). This allowed EEGLAB to identify and reject noisy channels before interpolating them back.

This was done to preserve all data leading up to the shot. Data was taken from 30 seconds prior to each shot.

Figure 1. Example of officer responding through simulation to high threat scenario.

2.4.2. Determining Inputs

Data from the police officer study was initially observed as a whole to determine which areas showed the most activation over the time leading to the shot. For the first set of sessions, the most stimulated area was Brodmann area 18. Other high activation Brodmann areas that were seen through the course of the study were areas 10, 20, and 21. After identifying these areas, a more in-depth analysis was done breaking the 30 second period into sections of 5 seconds in which the activation of each was recorded. To better understand the results, the common functionality of these Brodmann areas are described in the next few paragraphs.

Brodmann areas 9 and 10 are significate in brain operations involving memory. These areas are part of the dorsolated prefrontal cortex. While memory is associated with this Brodmann area including memory encoding, memory retrieval, and working memory, it also includes certain executive functions as well. These include "executive control of behavior", "inferential reasoning", and "decision making". There is a long list of additional processes, but the ones of note to this study include: error processing/detection, attention to human voices, metaphor comprehension, word-stem completion, and verb generation [27].

The prestriate cortex, Brodmann area 18, is the second major area in the visual cortex, and the first region in the visual association area. The neurons in this area consist of simple visual characteristics such as, orientation, spatial frequency, size, color, and shape. In addition, the V2 cells also respond to various complex shape characteristics, such as the orientation of illusory contours and whether the stimulus is part of the figure or the ground. Brodmann area 18 is also important in object recognition memory. Some more specific associated functions include detection of light intensity, tracking visual motion patterns, discrimination of finger gestures, word and face encoding, and horizonal saccadic eye movements [27].

The next Brodmann area of interest is area 20, the inferior temporal gyrus, which is part of the temporal cortex. This area is associated with high-level visual processing, language understanding, and recognition memory. Other functions worth noting is visual fixation and dual working memory task processing. Lastly, Brodmann area 20 is attributed to intentions to others, also known as theory of mind [27].

Area 21 is located in the middle temporal Gyrus. While its exact function is unclear, it is related to different functions such as processing distance, recognition of known faces, deductive reasoning, observation of motion, processing of complex sounds, and sentence generation. It is also worth noting again that attribution of intentions to others is listed for this Brodmann area as well. Examples of sLORETA data obtained from the officers are shown in **Figure 2** and **Figure 3**. The data is then organized into excel sheets to prepared to be uploaded into the fuzzy controller [27].

3. Fuzzy Controller

A fuzzy controller to analyze the collected EEG data was developed and

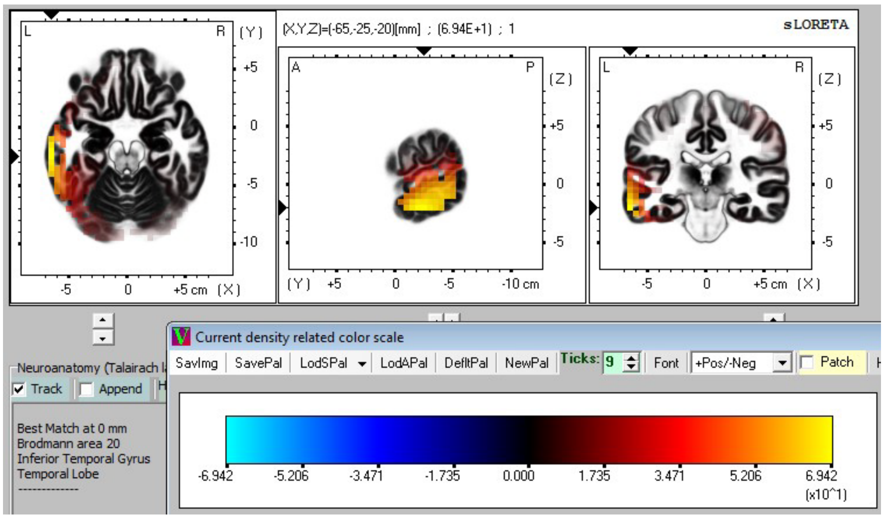

Figure 2. Baseline sLORETA (low resolution brain electromagnetic tomography) example.

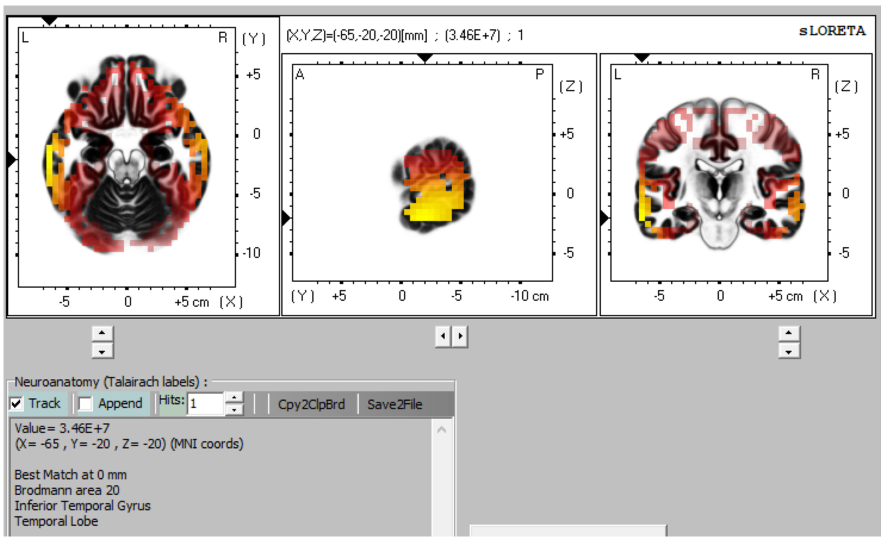

Figure 3. sLORETA (low resolution brain electromagnetic tomography) example from one officer just prior to decision to shoot (5 second prior to shooting) in high threat situation.

programmed with MATLAB's Fuzzy Toolbox through a Mamdani controller scheme, a centroid based method. The fuzzy controller was used to analyze the data by correlating the levels of activation of every participant. The subjects (*i.e.* police offices) were compared within each other to setup the constraints of the controller. The controller then determined how well each subject preformed within the study compared to other subjects in the study. A membership value determined how strong the brain activation of the subject was. These values were then processed through the controller with the help of the rules set up. The process utilized in this study for determining these rules came from an understanding of each Brodmann area, as these functions were then mapped to certain outputs shown in Figure 4 [27]. Some basic rules for these are coded in, but it is

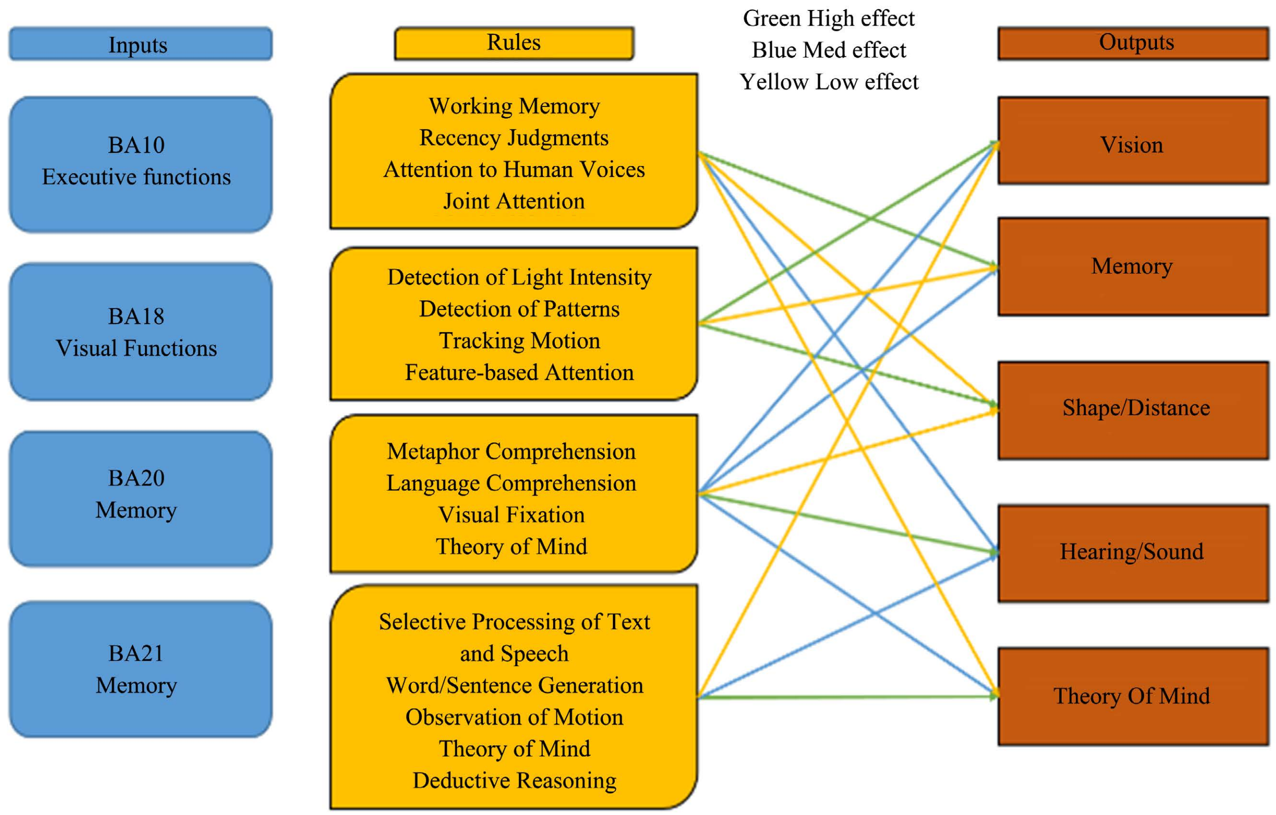

Figure 4. Rule generation for study.

suggested that tuning should be done based on the data to achieve the desired results. It is not necessary to lay out every conceivable rule combination as the controller is designed to utilize efferently what is given.

When the program runs, a window will pop up displaying the current state of the controller, including the inputs and outputs and a box in the middle that contains the rules for the interactions. It is then possible to plot inputs in a 3-D mesh using the surface command under view or to visualize any given input with the rules command in the same area. The 3-D mesh is shown in Figure 5. The process of creating rules in the script is shown in Figure 7. The script requires a certain syntax for the rules to be added. The "==" sign is used for inputs to show that a particular variable is equal to high, med, or low. "BA18==High => Vision=High" means that when Brodmann area 18 is high then this output vision output is high. There is also coding for "or" and "and" shown by | for or and & for and. In addition, the "~=" sign can be used to show that the output is true when the input is not equal to low. "BA20~=Low & BA18==High => Vision=High" means that when Brodmann 20 is not low and Brodmann area 18 is high then vision is high. The rule variable is setup with the first rule being rule(1)=. The rest of the rules should follow the same format of rule(end+1)= which adds the current rule to the end of the rule matrix, which ultimately gets merged into the controller. The interactions are shown in the ruler viewer (Figure 6).

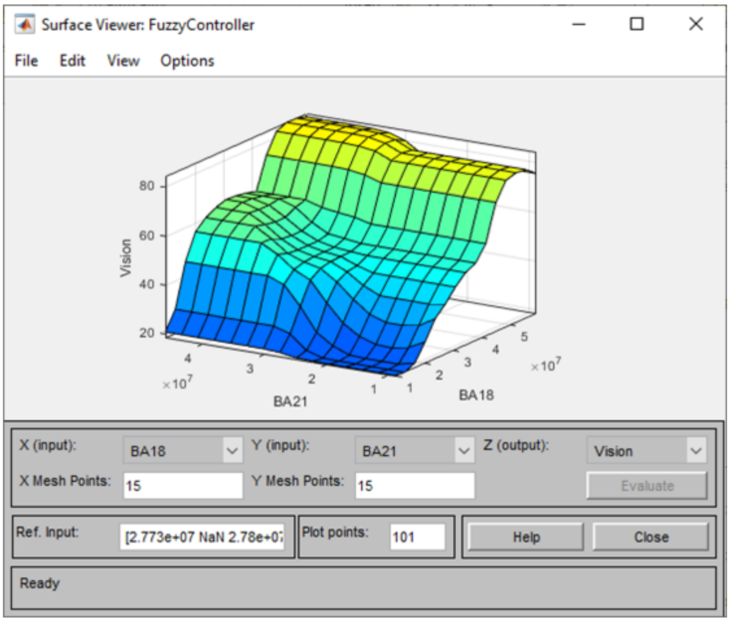

Figure 5. Surface viewer 3-D Mesh for the interaction between Brodmann areas 18 and 21 on vision.

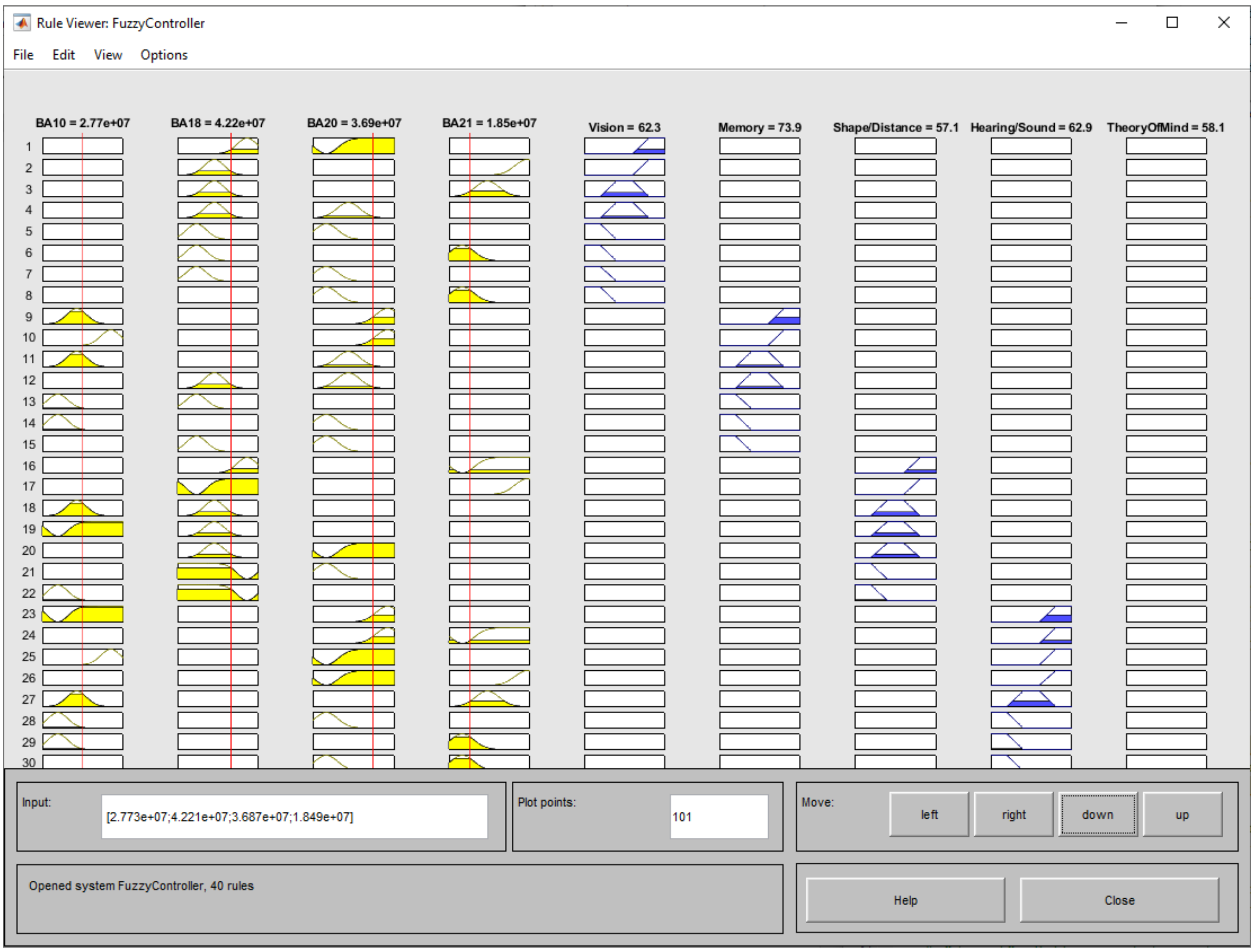

Figure 6. MATLAB rule viewer showing the breakdown of outputs based on rules.

4. Attained Results

The script automatically processed the rules and calculations for each subject and session. A heat map was created which displayed the full output (Figure 7). To offset the fact that defuzzification with the centroid method never gives a score of 100, the data was normalized from 1 to 100. The script was run, and data analyzed incrementally which allowed the rules to be evaluated and tuned each iteration for more accurate results. The script also displays z-score data based on local and global data as shown in Figure 8 and Figure 9.

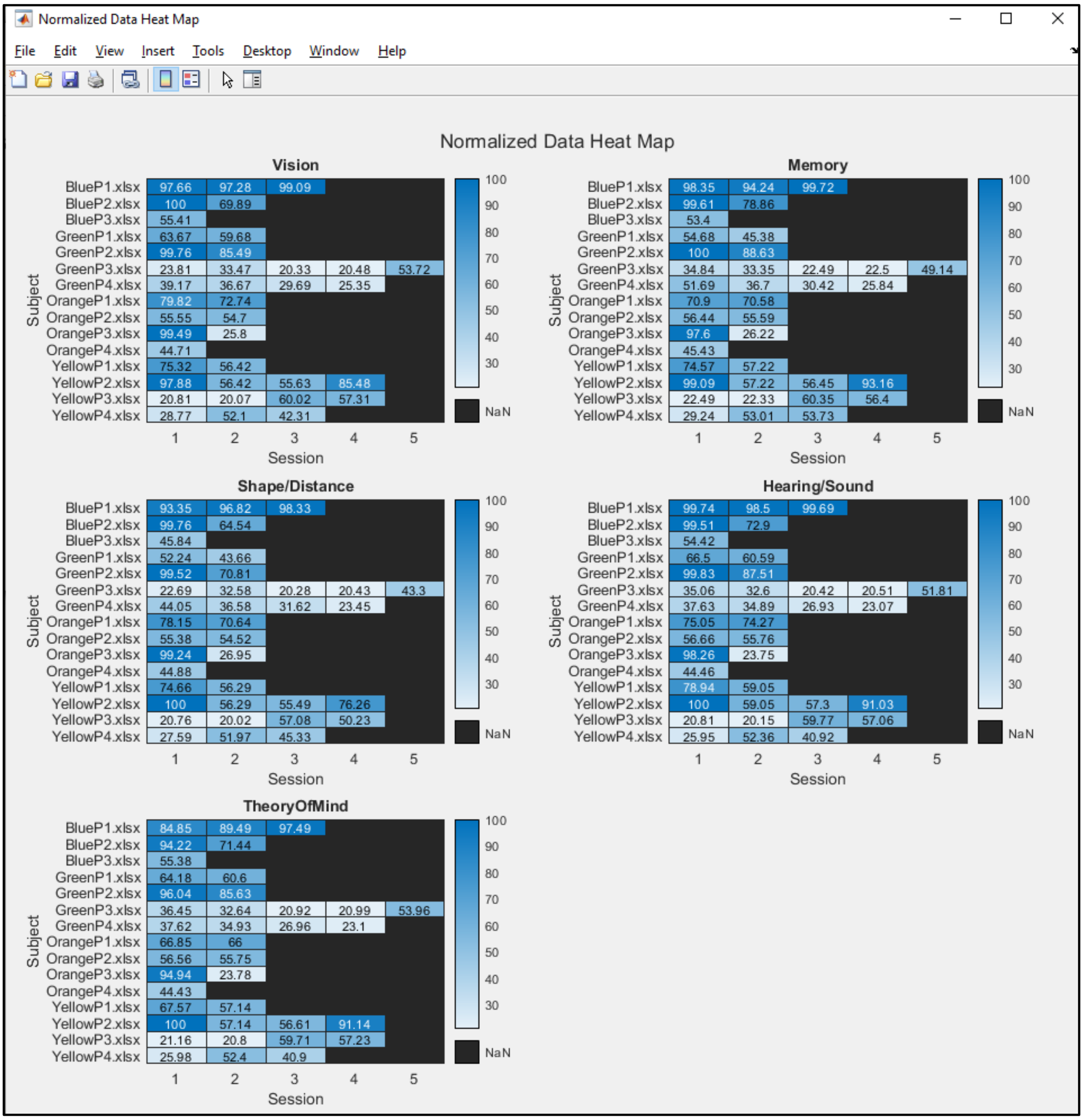

Figure 7. Normalized output data Heatmap.

Figure 8. Z-score local output data Heatmap.

An additional analysis utilized the outputs as data points in a 5th dimensional space. This allows for the distance formula to calculate how different (far away) or similar (close) the datapoints are. The results of this analysis are presented in a heatmap which is used to show the distance between each session (**Figure 10**). The darker colors indicate data that is further apart, and the lighter colors represent data that shares a similar area in 5th dimensional space, representing sameness in the datapoints.

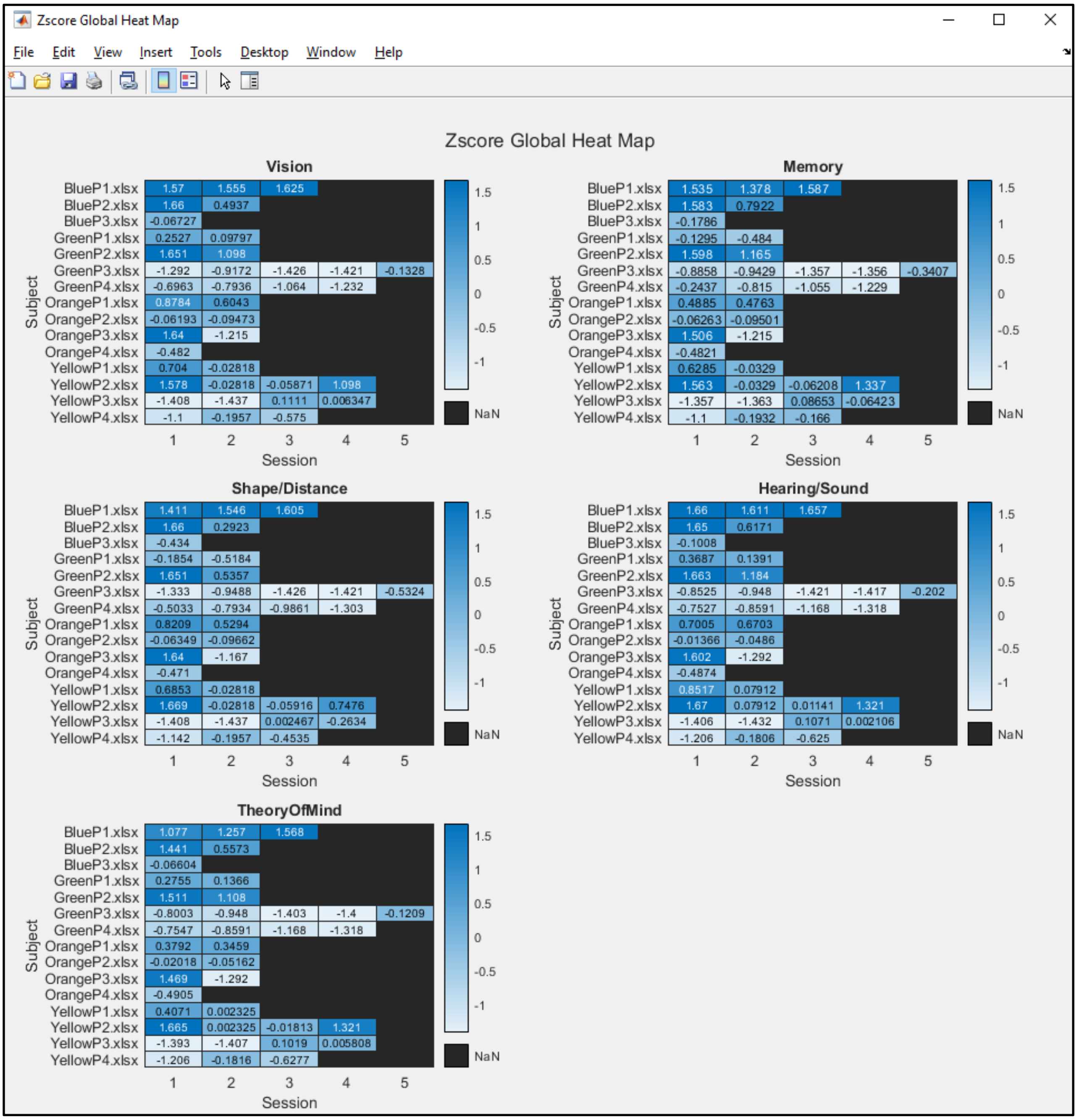

Figure 9. Z-score global output data Heatmap.

The data presented thus far has been a subset of the collected data in the study. Due to the nature of the way the inputs are setup, data with a standard deviation greater than two would skew the data making it more difficult to analyze the rest of the data. While the data variations can still be seen in the smaller data, the vastly larger data skews the results by shifting the average and standard deviation much higher than manageable. Figure 11 shows the z-score local data for the complete set of data. All datapoints that were over two standard deviations were ultimately removed.

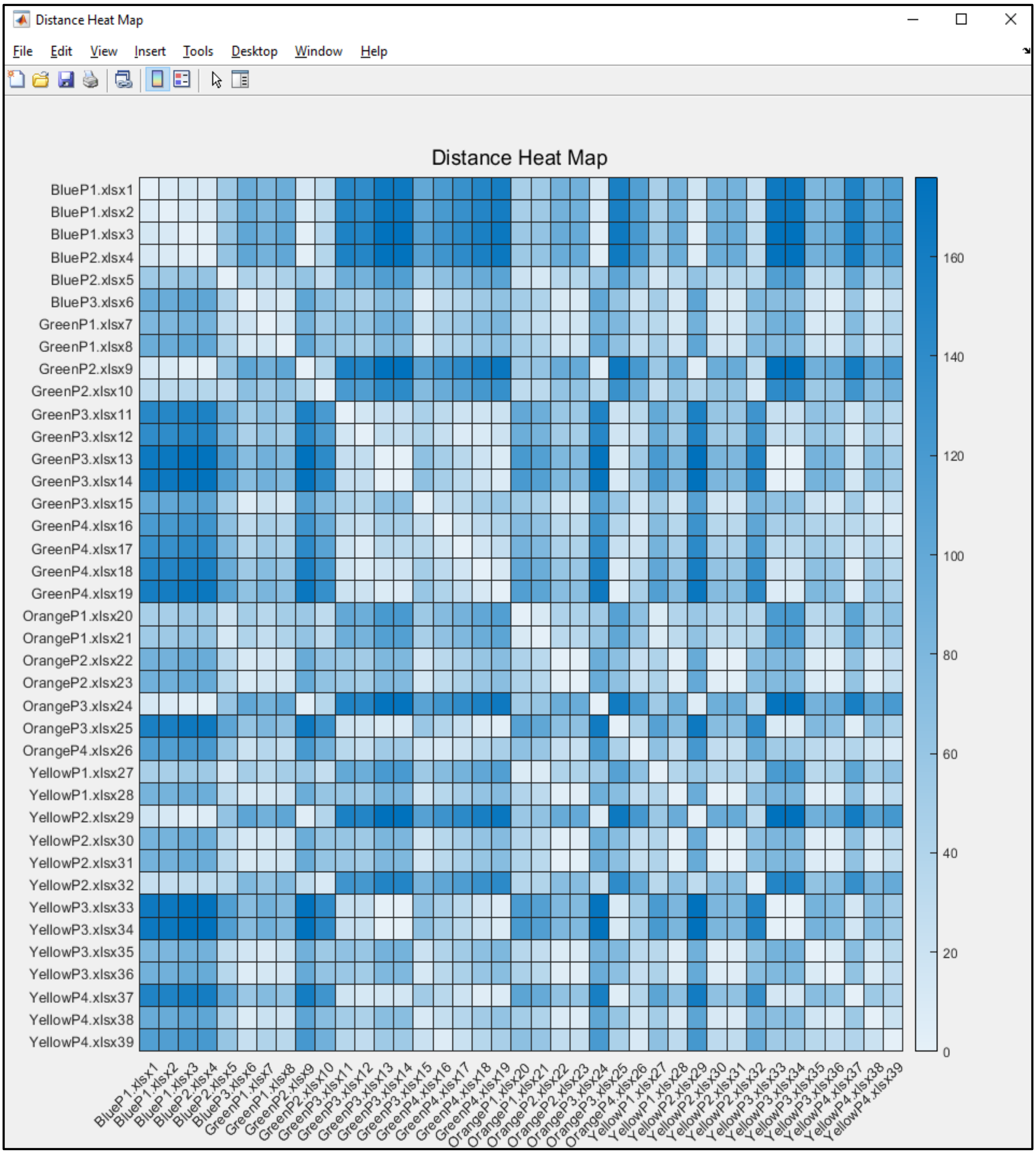

Figure 10. Distance heat map data.

The complete normalized data heat map can be seen in **Figure 12**. For all the Police data, the scenarios were organized by participant, and then by color. Each color represents a certain scenario type. Blue scenarios are road stops. Orange scenarios are combat operations involving SWAT or hostages. Green relates to routine and welfare checks. The last is Yellow, representing threat responses to a location such as a public library or a place of work.

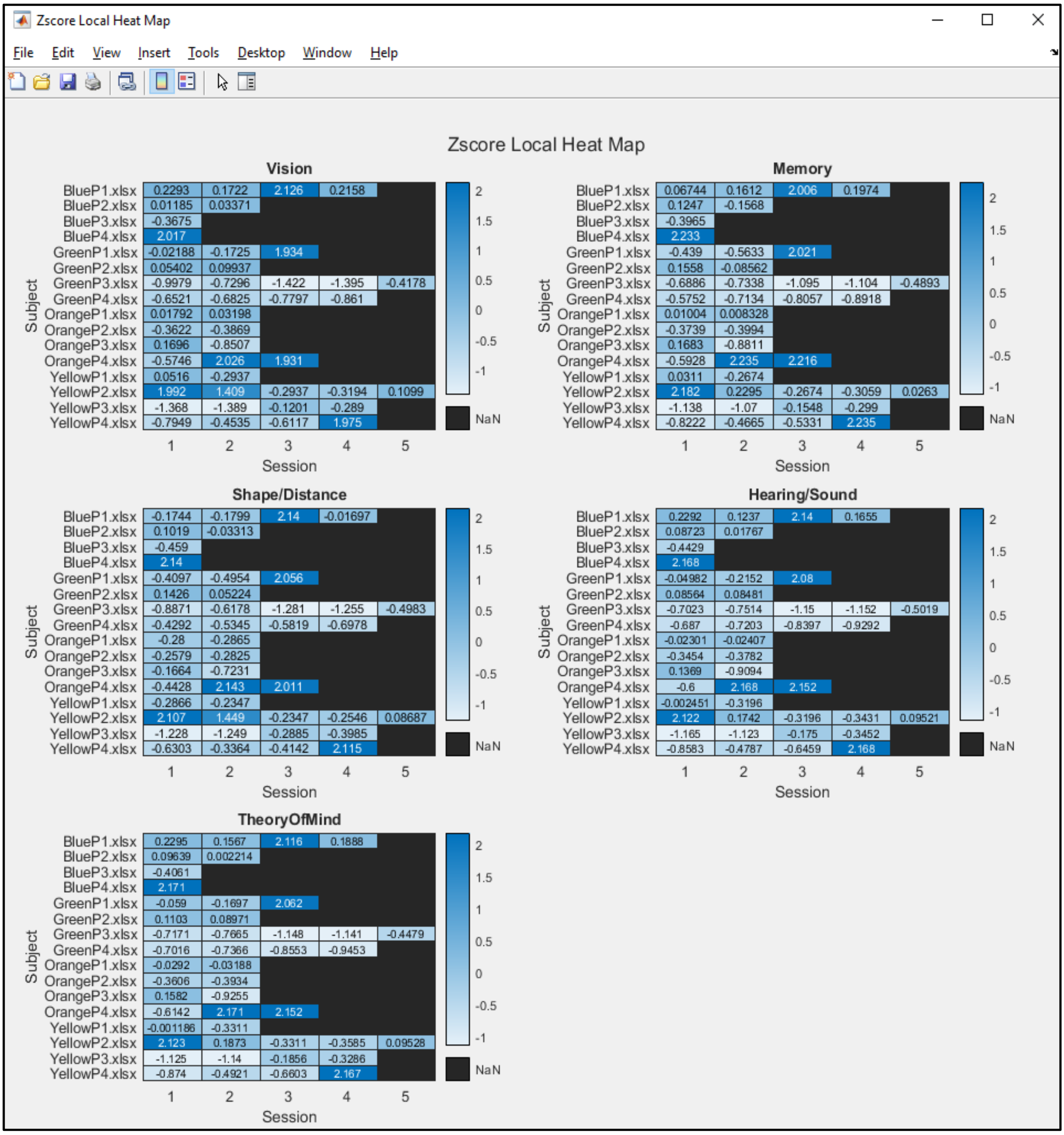

Figure 11. Complete local z-scores for police data.

5. Conclusions of the Study

The police study was broken into four different data categories. These included road stops (blue); routine and welfare checks (green); combat operations (orange); and threat response (yellow) (Tables 1-4). The presented tables all follow the same format, where a score of one indicates a high brain activity, and a score of five represents the lowest observed brain activity. Subjects P1 and P2 were the lesser experienced officer while Subjects P3 and P4 were the veteran officers.

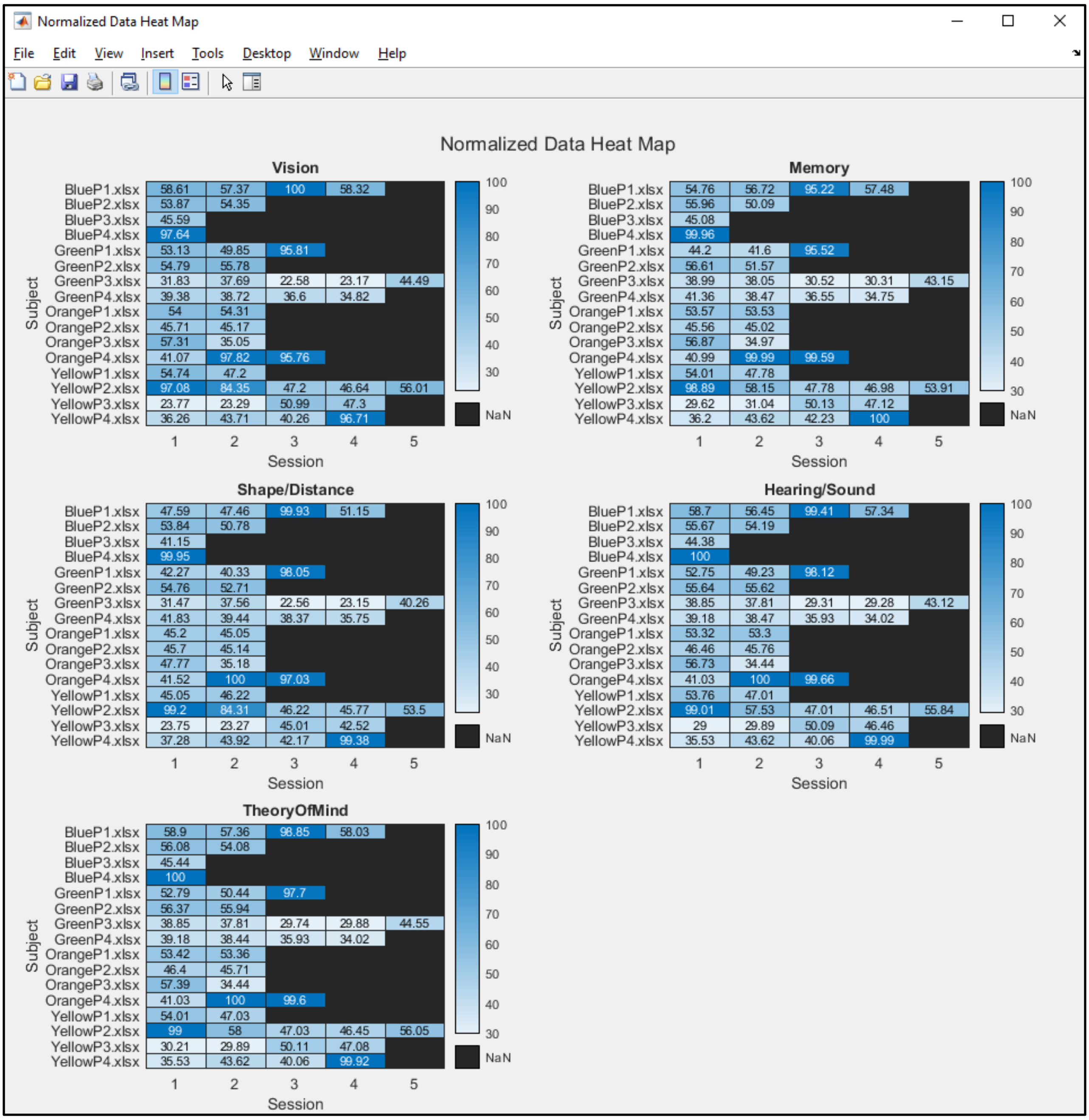

Figure 12. Complete normalized police heat map data.

Table 1. Road stop scenario rankings.

Road Stops(Blue)						
Subject	Type	Vision	Memory	Shape/Distance	Hearing/Sound	Theory Of Mind
P1	<Five Years	2.67	2.33	3.67	1.33	5.00
P2	<Five Years	2.50	2.00	3.50	3.00	4.00
P3	>Five Years	1.00	4.00	5.00	3.00	2.00

Table 2. Routine and welfare checks scenario rankings.

Routine and Welfare Checks (Green)						
Subject	Type	Vision	Memory	Shape/Distance	Hearing/Sound	Theory Of Mind
P1	<Five Years	3.00	4.00	5.00	1.50	1.50
P2	<Five Years	3.50	1.00	4.50	2.00	4.00
P3	>Five Years	3.00	2.20	5.00	3.00	1.80
P4	>Five Years	2.50	1.25	2.25	4.75	4.25

Table 3. Combat operations scenario rankings.

Combate Opertaions (Orange)						
Subject	Type	Vision	Memory	Shape/Distance	Hearing/Sound	Theory Of Mind
P1	<Five Years	1.50	4.00	2.50	2.00	5.00
P2	<Five Years	4.00	3.00	5.00	1.00	2.00
P3	>Five Years	2.00	3.00	1.50	4.00	4.50
P4	>Five Years	3.00	1.00	2.00	4.00	5.00

Table 4. Threat response scenario rankings.

Threat Response (Yellow)						
Subject	Type	Vision	Memory	Shape/Distance	Hearing/Sound	Theory Of Mind
P1	<Five Years	3.00	3.00	4.00	1.00	4.00
P2	<Five Years	4.25	2.50	4.00	1.50	2.00
P3	>Five Years	2.50	1.75	5.00	3.25	2.50
P4	>Five Years	3.00	1.00	3.33	4.00	3.67

Each scenario had five calculated outputs. These included *vision*, *memory*, *shape*/ *distance*, *hearing*/ *sound* and *theory of mind*. These values were all calculated individually for each scenario (**Figure 13**). Officer P4 did not participate in any scenario that would be considered a road stop, so BlueP4 has been excluded from the data. The officers competed a considerably high number of studies to be *analyzed* individually, thus, the average ranking for each output and each category were computed in (**Figure 14**). These values were then organized into the tables shown before. The results of the road stops are discussed first starting with the lesser experienced officers. Then, the results obtained from the more experience officers are presented.

Officer P1 was a lesser experienced officer. In this study, he completed three road stop scenarios. During these scenarios, the most activated areas of Officer

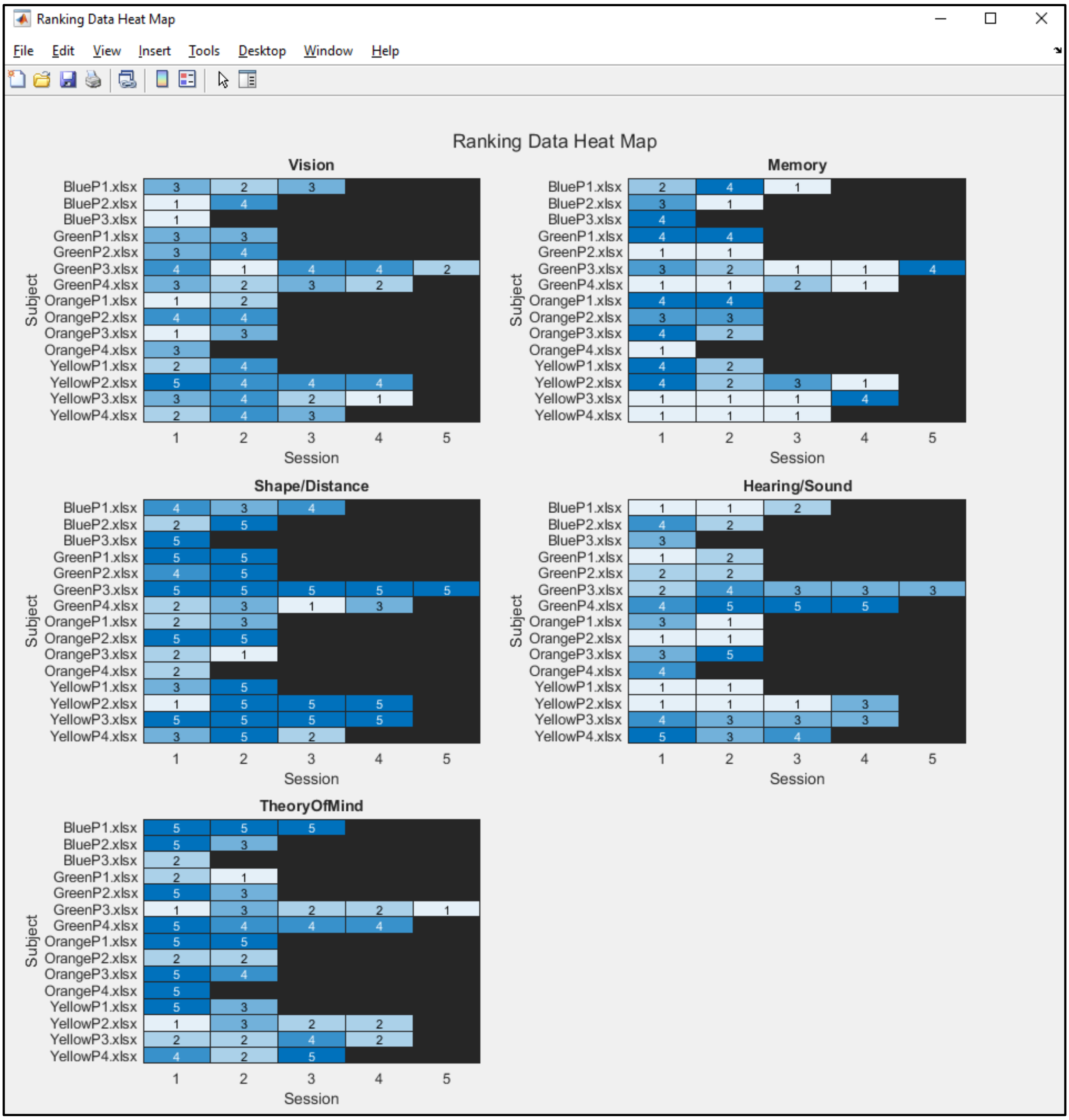

Figure 13. Ranking data heat map.

P1's brain was related to hearing/sound. This was followed by memory, which indicates that the officer chose to listen and correlate sounds during the road stops. The next outputs were vision and shape/distance. These outputs convey that the officer was still aware of their surroundings, but his theory of mind score shows that they failed to consider what the civilian was thinking or planning.

Officer P2 was also a lesser experienced officer. For the two road stop scenarios completed, *memory* was the highest. *Vision* was the second highest meaning

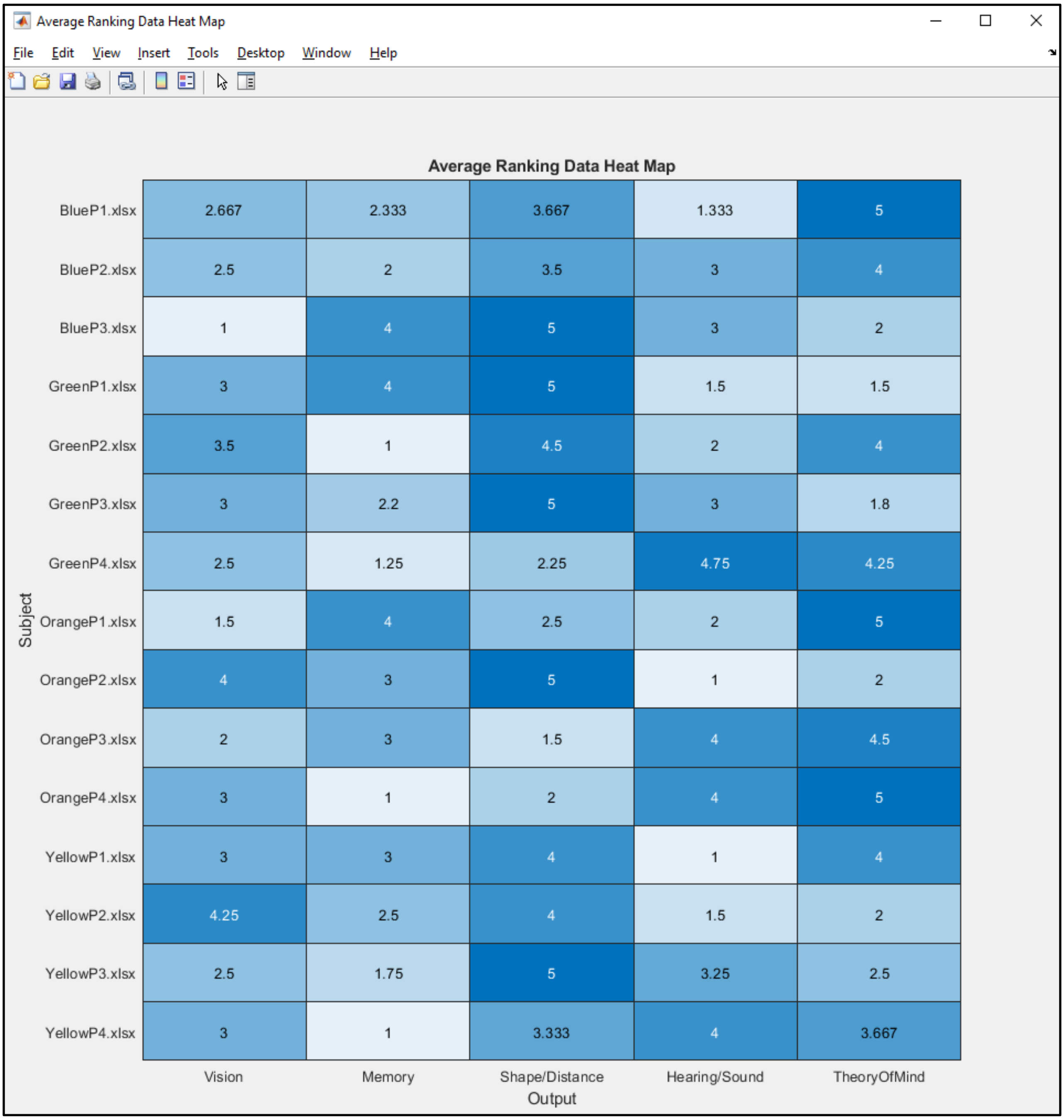

Figure 14. Average ranking data heat map.

that the officer was trying to remember what he was seeing or what his training taught him to do in this situation. This was followed by the perception-based outputs, *shape*/*distance* and *hearing*/*sound*, as more means of assessing the situation. Lastly, theory of mind scored a four.

The experienced Officer P3 utilized *vision* and *theory of mind* in his one road stop scenario. Based on what he could see and thought the civilian was going to do, he did not put much activation into *memory* or *shape*/*distance*. *Shape*/*distance*, in this study, is interpreted as determining if an object is a weapon, and this officer did not think further or did not need to think further about any shapes. *Hearing*/*sound* scored a three, which means he was listening for additional information.

The next category is the routine and welfare checks. Officer P1 participated in two of these scenarios. The highly ranked outputs for these scenarios were *theory of mind* and *hearing*/*sound*. Listening and trying to understand the civilians corresponds well to welfare checks. *Vision* ranked next as a method of examining the situation with some training memories following after. *Shape*/*distance* was ranked last meaning it was either not considered or the weapon was already identified.

Officer P2 used a different approach than that of Officer P1, who relied heavily on *theory of mind*. Officer P2 partook in two scenarios and decided to believe in his training, giving *memory* his highest score. This was followed by *hearing*/*sound* related to talking and the environment. *Vision* ranked third with *theory of mind* fourth as additional ways to assess the situation. *Shape*/*distance* was the lowest for this Officer as well leading to a similar conclusion that the weapon was either visible or not considered.

Officer P3 took a similar approach to that of Officer P1, utilizing *theory of mind* as his highest scored output. Officer P3 was involved in five routine and welfare check scenarios. As an experienced officer, using *theory of mind* in tandem with *memory* allowed this officer to assess the situation. *Hearing*/*sound* and *vision* received scores of three as perception-based skills. *Shape*/*distance* fell in last again leading to the same conclusion of a visible weapon, or that the weapon was not considered.

Officer P4 was the other experienced officer. Officer P4 logged four routine and welfare check scenarios. Officer P4 had a similar approach to that of Officer P2, who favored *memory* over *theory of mind*. Officer P4 was aided by his experience and kept keenly aware of weapons with a highly ranked *shape*/*distance* and *vision*. Lastly, *hearing*/*sound* and *theory of mind* were both ranked last. This Officer was potentially able to size up the situation without the need of these skills.

The third category is combat operations. Officer P1 was evaluated on two scenarios. During these scenarios, Officer P1 favored his perception-based skills highly such as *vision*, *shape*/*distance*, and *hearing*/*sound*. *Memory* was ranked fourth meaning that combat operations were already ingrained into his body. *Theory of mind* ranked last meaning that it had little or no perceived use in these scenarios.

Officer P2 had a hostage situation as one of his two scenarios, with the other being a Special Weapons and Tactics (SWAT) operation. *Hearing*/*sound* was his highest, but *theory of mind* came in second. In operations like these, communicating and understanding the intentions of the squad mates is important. Also, for hostage situations, listening and trying to diffuse the situation is respectable. *Memory* was used to maintain proper protocol. *Vision* and *shape*/*distance* came in last, likely due to the straightforwardness of the scenarios.

Officer P3 partook in two combat operation scenarios. In his scenarios, he relied heavily on assessing the situation visually. He fell back onto his *memory*, as a more experienced officer, to handle the scenarios. Lastly, *hearing*/*sound* and *theory of mind* were not utilized or had no perceived value in these scenarios.

Officer P4 only recorded one scenario. His *memory* ranked the highest meaning that similar operations or tactics were being considered. Outside of that, Officer P4 followed similar suit to Officer P3 relying on his *visual* skills to assess the situation, leaving *hearing*/*sound* and *theory of mind* to be considered unnecessary for this scenario.

The last category considered is threat response. Officer P1 conducted two scenarios in this category. *Hearing*/*sound* ranked his highest, with everything else falling to the lower half of the scoring. *Vison* and *memory* both had a score of three as ways to help assess and visualize the scenario. One of the scenarios was a robbery suspect running, so listening and trying to understand where the robber would go, also falls into these skills.

Officer P2's threat response scenarios consisted of five scenarios, of which four were shootings. The highest scores were *hearing*/*sound* and *theory of mind*. These were attributed to locating the shooters with sound and determining their potential actions. *Memory* was also high, relating to his training or memorizing his surroundings. The lowest scores were *vision* and *shape*/*distance* meaning that line of sight might have been obscured by walls or objects.

Officer P3 handled four close combat encounters, one of which left his partner disarmed. The activation spread was high for *vision*, *memory*, and *theory of mind*. Being close to the encounters already, *shape*/*distance* and *hearing*/*sound* were not deemed as important as being able to see remember and predict the actions of the suspect in question.

For Officer P4, there were three scenarios to be completed. Officer P4 had used his *memory* consistently and this category is no different. His experience aids him in assessing situations, but in this case, the rest of his outputs were low. *Vision*, *shape*/*distance* were both scored around three as the officer's means of visually interpreting the scenario. Officer P4 also partook in the partner disarmed scenario, but Officer P4's *theory of mind* suggests that he was not worried about how his partner would react and rather focused on the task at hand.

Overall, this study represents an interesting look into the minds of the officers. Comparing and contrasting the lesser experienced officers with the veteran officers allowed for a greater understanding of the methods taken to complete each category of scenarios. These insights allow for a better understanding of each officer's skill set and approach to the given problems. Each set of scores painted a picture of how the subject's brain was acting during his task, which lined up with the expected results given the scenarios. Furthermore, the results from this work can be utilized for personal evaluation, in order to see how each officer measures up to others. Identifying which types of scenarios target which parts of the brain would aid in further skill set training. This would enable officers to determine scenarios that would be worth reviewing or replaying to train areas of their brain.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

References

[1] Bittner, E. (1970) The Functions of the Police in Modern Society: A Review of Background Factors. Current Practices, and Possible Role Models (No. 2059). National Institute of Mental Health, Center for Studies of Crime and Delinquency.

[2] Haufler, A.J., Spalding, T.W., Santa, M.D. and Hatfield, B.D. (2000) Neuro-Cognitive Activity during a Self-Paced Visuospatial Task: Comparative EEG Profiles in Marksmen and Novice Shooters. *Biological Psychology*, **53**, 131-160. https://doi.org/10.1016/S0301-0511(00)00047-8

[3] Stewart, S.L. and Kirkham, J.A. (2020) Predictors of Individual Differences in Emerging Adult Theory of Mind. *Emerging Adulthood*, **10**, 558-565.

[4] Hedy, S.W., Jeffrey, M.B., Julie, S.T., David, A. and Shmuel, P.R. (2012) Fostering and Evaluating Reflective Capacity in Medical Education: Development of the REFLECT Rubric for Evaluating Reflective Writing. *Academic Medicine*, **87**, 41-50. https://doi.org/10.1097/ACM.0b013e31823b55fa

[5] Moon, J.A., (2004) A Handbook of Reflective and Experiential Learning, Theory and Practice. Routledge Falmer, London and New York.

[6] Berner, E.S. and Graber, M.L. (2008) Overconfidence as a Cause of Diagnostic Error in Medicine. *The American Journal of Medicine*, **121**, S2-S23. https://doi.org/10.1016/j.amjmed.2008.01.001

[7] Mamede, S., Schmidt, H.G. and Penaforte, J.C. (2008) Effects of Reflective Practice on the Accuracy of Medical Diagnoses. *Medical Education*, **42**, 468-475. https://doi.org/10.1111/j.1365-2923.2008.03030.x

[8] Mamede, S. and Schmidt, H.G. (2004) The Structure of Reflective Practice in Medicine. *Medical Education*, **38**, 1302-1308. https://doi.org/10.1111/j.1365-2929.2004.01917.x

[9] Tremayne, P. and Barry, R.J. (2001) Elite Pistol Shooters: Physiological Patterning of Best vs. Worst Shots. *International Journal of Psychophysiology*, **41**, 19-29. https://doi.org/10.1016/S0167-8760(00)00175-6

[10] Bowden, E.M., Jung-Beeman, M., Fleck, J. and Kounios, J. (2005) New Approaches to Demystifying Insight. *Trends in Cognitive Sciences*, **9**, 322-328. https://doi.org/10.1016/j.tics.2005.05.012

[11] Kounios, J., *et al.*, (2006) The Prepared Mind: Neural Activity Prior to Problem Presentation Predicts Subsequent Solution by Sudden Insight. *Psychological Science*, **17**, 882-890. https://doi.org/10.1111/j.1467-9280.2006.01798.x

[12] Dietrich, A. and Kanso, R. (2010) A Review of EEG, ERP, and Neuroimaging Studies of Creativity and Insight. *Psychological Bulletin*, **136**, 822-848. https://doi.org/10.1037/a0019749

[13] Sandkühler, S. and Bhattacharya, J. (2008) Deconstructing Insight: EEG Correlates of Insightful Problem Solving. *PLOS ONE*, **3**, e1459. https://doi.org/10.1371/journal.pone.0001459

[14] Halliburton, C.M. (2011) Race, Brain Science, and Critical Decision-Making in the

Context of Constitutional Criminal Procedure. *Gonzaga Law Review*, **47**, 319-340.

[15] Correll, J., Park, B., Judd, C.M., Wittenbrink, B., Sadler, M.S. and Keesee, T. (2007) Across the Thin Blue Line: Police Officers and Racial Bias in the Decision to Shoot. *Journal of Personality and Social Psychology*, **92**, 1006-1023. https://doi.org/10.1037/0022-3514.92.6.1006

[16] Correll, J., Wittenbrink, B., Crawford, M.T. and Sadler, M.S. (2015) Stereotypic Vision: How Stereotypes Disambiguate Visual Stimuli. *Journal of Personality and Social Psychology*, **108**, 219-233. https://doi.org/10.1037/pspa0000015

[17] Senholzi, K.B., Depue, B.E., Correll, J., Banich, M.T. and Ito, T.A. (2015) Brain Activation Underlying Threat Detection to Targets of Different Races. *Social Neuroscience*, **10**, 651-662. https://doi.org/10.1080/17470919.2015.1091380

[18] Payne, B.K. (2001) Prejudice and Perception: The Role of Automatic and Controlled Processes in Misperceiving a Weapon. *Journal of Personality and Social Psychology*, **81**, 181-192. https://doi.org/10.1037/0022-3514.81.2.181

[19] Amodio, D.M. (2014) The Neuroscience of Prejudice and Stereotyping. *Nature Reviews Neuroscience*, **15**, 670-682. https://doi.org/10.1038/nrn3800

[20] Kubota, J.T., Banaji, M.R. and Phelps, E.A. (2012) The Neuroscience of Race. *Nature Neuroscience*, **15**, 940-948. https://doi.org/10.1038/nn.3136

[21] Broomé, R.E. (2011) An Empathetic Psychological Perspective of Police Deadly Force Training. *Journal of Phenomenological Psychology*, **42**, 137-156. https://doi.org/10.1163/156916211X599735

[22] Zanow, F. and Knösche, T.R. (2004) ASA-Advanced Source Analysis of Continuous and Event-Related EEG/MEG Signals. *Brain Topography*, **16**, 287-290. https://doi.org/10.1023/B:BRAT.0000032867.41555.d0

[23] Domingues, C.A., *et al.* (2008) Alpha Absolute Power: Motor Learning of Practical Pistol Shooting. *Arquivos De Neuro-Psiquiatria*, **66**, 336-340. https://doi.org/10.1590/S0004-282X2008000300010

[24] Delorme, A. and Makeig, S. (2004) EEGLAB: An Open Source Toolbox for Analysis of Single-Trial EEG Dynamics Including Independent Component Analysis. *Journal of Neuroscience Methods*, **134**, 9-21. https://doi.org/10.1016/j.jneumeth.2003.10.009

[25] Thompson, T., Steffert, T., Ros, T., Leach, J. and Gruzelier, J. (2008) EEG Applications for Sport and Performance. *Methods*, **45**, 279-288. https://doi.org/10.1016/j.ymeth.2008.07.006

[26] Delorme, A., Sejnowski, T., and Makeig, S. (2007) Enhanced Detection of Artifacts in EEG Data Using Higher-Order Statistics and Independent Component Analysis. *NeuroImage*, **34**, 1443-1449. https://doi.org/10.1016/j.neuroimage.2006.11.004

[27] Trans Cranial Technologies (2012) Cortical Functions. Trans Cranial Technologies, Hong Kong.