Discussions

Volume 2 | Issue 1 Article 6

2023

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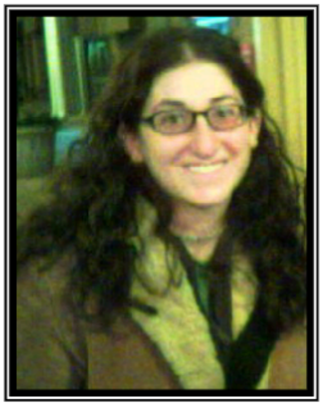
Recommended Citation
Schepp, Brooke (2023) "Individualized Behavioral and Imaging Analysis of Response Time, Accuracy, and Social Cognitive Load During Social Judgments in Adolescents," *Discussions*: Vol. 2: Iss. 1, Article 6.
DOI: https://doi.org/10.28953/2997-2582.1079
Available at: https://commons.case.edu/discussions/vol2/iss1/6

Individualized Behavioral and Image Analysis of Response Time, Accuracy, and Social Cognitive Load During Social Judgments in Adolescents



-Brooke Schepp-

Brooke Schepp is a senior at Case Western Reserve University where she is a triple major in Biology, Psychology, and Cognitive Science. She also has a minor in Chemistry. Aside from being active in the research community, Brooke has also been very active on campus. She acted as a director for the CWRU Film Society for two years and she is an active member of the Case Taekowndo club. She has also acted as an SI (supplementary instructor) for COGS 102: Introduction to Cognitive Neuroscience and is a member of Psi Chi, the national honor society in psychology. After graduating in May, Brooke will spend two months backpacking through Europe and then plans to attend graduate school in the fall.

-Acknowledgements-

I would like to thank Dr. Ciccia, Dr. Dzemidzic, Dr. Rothenberg, Dr. Wiliams, Dr. Tkach, and The Communication Sciences Department at Case Western Reserve University, for all of their help on this project. This work was supported by the American Speech-Language Hearing Foundation New Investigator's grant to the Second author and by a Howard Hughes Medical Institute (HHMI) Fellowship awarded to the first author.

ABSTRACT

Functional magnetic resonance imaging (fMRI) has become an invaluable tool in understanding the relationship between brain and behavior. This technique has become particularly important in the study of human social cognition. The current study focuses on the social cognitive judgment skills of late adolescents (ages 18 -21), and seeks to investigate four specific aims. These aims include the following: 1) To characterize the relationship of accuracy of responses and reaction time while making social judgments; 2) To describe the relationship between response accuracy and social cognitive load; 3) To identify the relationship between questions of increasing social cognitive demand and reaction time; and 4) to identify the interaction between response time, accuracy, and increasing social cognitive load. A secondary aim of this study is to complete an individualized functional imaging analysis taking into consideration each participants' accuracy and reaction time. This analysis will provide further insight into the brain-behavior relationship in human social cognitive function. Behavioral and imaging results of the present study will be reviewed.

INTRODUCTION

Social cognitive skills, such as the detection of sarcasm, the expression of humility, and the sharing of the conversational burden, are vital for successful social interactions with peers, especially during adolescence when individuals are faced with increasingly complex social interaction (Turksra 2000). The use of functional imaging technology has allowed investigators to examine the neural mechanisms responsible for social cognitive skills (Saxe 2006). Some of the brain regions identified as important for social cognitive behaviors include the superior temporal gyrus, anterior cingulate, fusiform gyrus, parahippocampal gyrus, and inferior parietal lobe (Ciccia, et al. 2006).

The present study investigates the behavioral effects of reaction time, accuracy, and level of social cognitive load on the functional imaging methodology currently used by Ciccia (2006) to study brain activation patterns during social cognitive judgments in adolescents. A secondary aim of this study focused on using the results of the behavioral analysis to customize the functional imaging analysis. Tailoring the functional imaging analysis to each participant's social decision reaction time will allow for a more valid investigation of the imaging results.

METHODS

Participants

All participants in this study met the following inclusion criteria: 1) No history of neurological disease or disorder (including acquired brain injury); 2) No history of learning or reading disability or gifted states; 3) No history of claustrophobia; and 4) No metal in their body (e.g., pacemaker wiring). The participants ranged in age from 18 to 21 years, with a mean age of 19 years, and included four male and four female participants.

A total of fourteen participants completed the study; however, only data from eight of these participants could be analyzed. Four participants could not complete the study because of illness at the time of the scan, one participant was removed from data analysis because of clinical findings discovered when the file was reviewed by a Radiologist, and another participant was removed from data analysis because of equipment malfunction during the functional imaging protocol.

Imaging Tasks and Behavioral Procedure

Tasks:

Participants were shown videos of different social conversation interactions that occurred between adolescent actors (Turkstra, 2000). Conversations focused on topics that were identified by adolescents as appropriate and likely to be brought up in normal conversation. These included topics such as after school activities, classroom performance, friendships, and dating. Social conversational skills that were depicted in these interactions included detection of sarcasm, expression of humility, and sharing conversational burden.

After watching each video, participants were asked to make a series of social judgments of increasing difficulty based on the interactions just viewed (Figure 1). The first social judgment, requiring minimal social cognitive demand, was, "Is X interested?" (X referring to a specific actor in the video clip). The participants were then shown the same clip a second time and asked, 'Does X get it [the meaning]?' This question required a moderate amount of cognitive demand. After a final showing of the video clip, the participants were asked the high-level cognitive demand question, 'Does Y think that X gets it [the meaning]?' where Y refers to the second actor in the conversation.

Figure 1: This figure shows video clips from the paradigm with the three questions used in the study. In this video, the female character is trying to elicit sympathy and compassion from the male character by telling him that her dog died this morning. The male character is not paying much attention to her or her story. The video was shown three times to each participant, with one question being presented in this order after each video clip.

A total of three blocks, with five video vignettes in each, were shown to the participants. Each of these videos was shown three times within a block. Each video and each block was followed by a period of rest of either four or six seconds where the participant was presented with a blank screen. There was a sixteen second break following the last question in each block. Figure 2 depicts the paradigm design for each block, including rests. Each video clip, including decision making time, equaled a total of ten seconds. Following each clip, the participants had a three second window to give a response, although it was possible for them to give a response even after the next video had started. Each block took a total of 3:06 minutes.

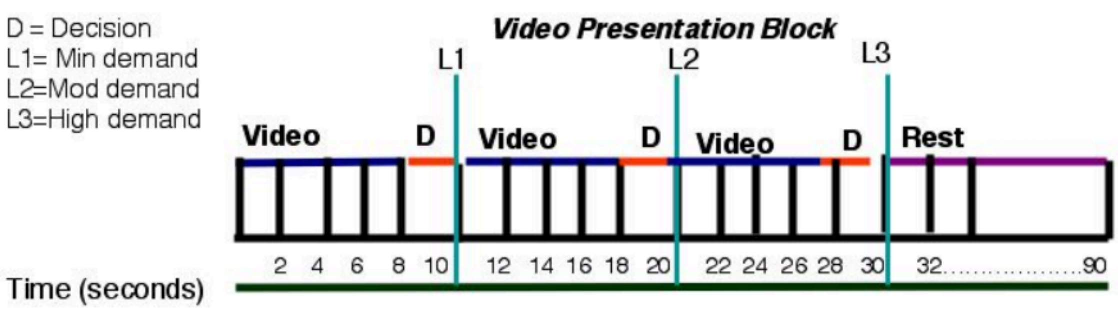


Figure 2: Video Presentation Block, an example of the video design shown in this experiment. The participants were shown a video example of a common social conversation. After viewing the video, the participants were asked to make a series of social judgments, which were presented in an order of increasing difficulty. The participants saw each video clip three times, each time followed by a different question. There were five individual video clips in each block.

Procedure:

Informed consent was obtained and a practice session was completed before the participants entered the scanner. The practice session lasted one hour and consisted of reviewing social rules and practicing the video paradigm on a computer. The review of social rules included questions such as: “What makes a good/ bad communication partner? What makes a conversation go well? How do you know?”

The functional imaging protocol took place at the Cleveland Clinic Foundation and was completed within 48 hours of the practice session. Prior to beginning the functional imaging protocol, the video paradigm was practiced outside the scanner for a second time and the imaging technician answered any questions the participant's may have had about the scanner.

Aside from watching the video paradigm, the participants were also required to make behavioral responses according to their social judgments. Participant responses were collected using 5DT virtual reality data gloves. The gloves were placed over the hands of the participants, who would then make minimal hand movements to register their response. The participants were instructed to move their left hand to indicate "no" and their right hand to indicate "yes". The participants were given the opportunity to practice this response pattern, with the gloves on, prior to completing the video protocol in the scanner and again between video block presentations.

To ensure the comfort and safety of participants during the fMRI protocol, time in the scanner was limited to one hour and a foam pad was placed under each persons' head and knees. Additionally, participants were in constant contact with the researchers via an audio system that allowed researchers to hear the participants at all times. Participants were also given a "panic button" which would alert the research staff of any type of emergency. Each participant removed any metal from their bodies (e.g. earrings) prior to entering the scanning area.

Data and Image Acquisition

Data for this study was acquired using a 3T Siemens Allegra MRI scanner located at the Cleveland Clinic Foundation. The video paradigm was presented via back-projection and a mirror was fixed to the head-coil in the scanner and was in line with the participants' field of vision. The trigger for the video paradigm was coordinated with data acquisition from the fMRI scanner through MATLABã software. The behavioral responses captured using the 5DT virtual reality gloves were coded and were reviewed by an independent member of the study at a later date.

The imaging protocol consisted of the following: Anatomic scans consisted of 3D Whole brain T1:T1 -weighted inversion recovery turboflash (MPRAGE), 120 axial slices, thickness 1.2mm, Field-of-view (FOV) 256mm x 256mm , TI/TE/TR =1900/1.71/900ms, flip angle (FA) 80º, matrix 256 x 128, receiver bandwidth (BW) = 32kHz. Imaging for the fMRI activation study: 101 EPI volumes of 32 interleaved axial slices were acquired using a prospective motion-controlled, gradient recalled echo, echoplanar acquisition (Thesen et al., 2000) with TE/TR/flip=39ms/2s/90º, matrix=64x64, 256mm x 256mm FOV; BW = 125 kHz.

Imaging Data Analysis

Imaging data were processed and analyzed using Statistical Parametric Mapping (SPM5) software developed by the Wellcome Department of Imaging Neuroscience at the University College in London (http://www.fil.ion.ucl.ac.uk/spm/software/spm5). Preprocessing analysis of the data included: slice timing correction, realignment and unwarping, co-registration, normalization to the MNI T1 template (Montreal Neurological Institute), and smoothing with a 6 mm isotropic Gaussian kernel. These preprocessing steps allow SPM to combine the functional and structural imaging data into a single image for analysis. Realigning takes all of the separate imaging files and puts them into the software program in the order in which they were taken. This process was completed for the structural imaging scans and the functional imaging scans separately. Another preprocessing step, spatial normalization, takes into account the normal variation in individuals head size. The images were then smoothed to accommodate differences in individual brain structures and prospective motion correction was used as a primary method to deal with participant movement within the scanner. Following this, grey-matter segmented and smoothed MPRAGE images were combined with mean EPI images averaged across subjects to create a single union image. Individual subject data were analyzed in a fixed effects model with the Canonical HRF as basis functions. The six realignment parameters (3 rotations and 3translations) were included as repressors. SPM identifies functionally activated coordinates and indicates cluster size. Significant cluster size was defined as 54 voxels or greater. The completion of these tasks allowed for a clear overlay of the functional imaging data over the structural data and the identification of activation in pre-specified regions of interest (Frackowiak, Friston, Frith, Dolan, Price, Zeki, Ashburner, & Penny, 2004).

Standardized Group Imaging Analysis

Ciccia and colleagues (2006) previous analysis of the group data looked at the brain activation patterns that persisted across all study participants. To analyze the group data, a single reaction time decision point was identified each social judgment. The ten second time point was selected because a preliminary inspection of the behavioral data indicated many participants registered their decisions at the ten-second mark. This data was then looked at in two ways: as a group image (where the 10 second decision points for all of the participants were averaged together), or as individuals (each individual participant's activation using the same ten second marker as the decision point). Activation patterns where then compared according to question difficulty to discover which brain areas are activated by different levels of social judgments (Ciccia, 2006).

Individual Imaging Analysis

The image analysis for the present study considered each participants brain activation patterns rather than grouped results as discussed by Ciccia and colleagues (2006). Although many of the decision points fell on the ten second mark, the actual variability in reaction times varied from in from 7.85 seconds to 12.05 seconds. The exact second of response was pinpointed from the behavioral glove response data. This temporal information was used to individualize the functional imaging analysis in SPM. These scans were then divided up into groups that correlated to question difficulty (i.e. all of the response times for the firsts question, 'Is X interested?' were put into one group, etc.) and these groups were compared against each other in order to find to activation effects that were specific to each question set. In other words, by subtracting out the activations caused by the simplest question (Is X interested?) from the activations caused by the most difficult question (Does Y think that X gets the meaning?) the areas of the brain used solely for the most difficult question become highlighted. The subtraction method allows researchers to see what brain areas are activated as adolescents are faced with more challenging social judgments.

The results from the customized individual analysis completed for this study were then compared to the individual analysis previously conducted by Ciccia and colleagues (2006) that used a standardized 10 second decision time.

Behavioral Data Analysis

The behavioral data analysis focused on the responses that the participants made while answering the social questions during the functional imaging protocol. The laser gloves allowed the computer software (MATLAB) to register each response as yes or no and to register the reaction time for each decision. Data for reaction time and yes/no responses were organized by subject, question type, block order, and accuracy in a way that was appropriate for statistical analysis. Researchers in the lab identified correct and incorrect answers based on agreed upon criteria. Each participant's responses were then coded as correct or incorrect and the data was entered into SPSSã statistical software (http://www.spss.com) to complete an analysis of the specific aims of this study which included: 1) the relationship of reaction time to response accuracy (correct and incorrect answers); 2) the relationship between reaction time and question type; 3) the relationship between accuracy and question type; 3)and the interactions between accuracy, question type, and reaction time.

RESULTS

Behavioral Data

It was first determined that all participants completed all three blocks. Only one participant failed to make social judgments (i.e. not giving a response when prompted with the questions) during the paradigm. This same participant also remained undecided on four responses (by moving both hands in response to a question, thus answering both yes and no). Since these six responses all occurred for the same participant and during the same block, results from that block were discarded. It was also noted that for the last participant response in each of the blocks was not collected by MATLAB. This left only fourteen question responses per block for analysis, resulting in a loss of twenty four responses of questions of type three. The information gleaned from the behavioral response data (reaction time, accuracy, and question type) were run though SPSS in order to determine main effects and the interaction effects these three variables.

Accuracy vs. Reaction Time vs. Question Type

The relationships between these three variables are very complex. These relationships are illustrated in Figure 3. The first thing to note is that the reaction time of all question one responses (both correct and incorrect) have a faster reaction time then questions of type two and type three. The response times of questions of type three appear slightly faster then those of type two. The second thing to note is that the reaction times of the correct responses are faster then the reaction times for incorrect responses. It is also of interest to note that there seems to be more variation in reaction times for incorrect answers as compared to correct answers.

A relationship that is not represented in this figure but what was clear in the data is that there were more correct responses then incorrect responses. Overall, there were 243 correct answers, 87 incorrect answers, and six undecided or null responses. Of these, questions of type one had the most correct responses, followed by questions of type two followed by questions of type three. Questions of type two had the most incorrect responses, with the number of incorrect responses being roughly the same for questions of type one and questions of type three. A MANOVA was run with all of the variables to determine the relationships between reaction time, accuracy, and question type. This test determined that there was a significant main effect for the relationship between these three variables (p = .000 for all variables). Additional post-hoc testing and testing of between subject effects revealed additional information about the nature of these relationships, which are discussed further in this section.

Accuracy vs. Question Type

Overall, there were 92 correct responses, 24 incorrect responses, and four null or undecided responses for questions of type one. There were 81 correct, 38 incorrect, and one null or undecided response for questions of type two, and there were 70 correct, 25 incorrect, and one null or undecided response for question three (not including the 24 missing question three responses). This data can be seen in Figure 4. Overall, it does not appear that question type has any real effect on accuracy. Questions of type one had the most correct responses, followed by questions of type two and then types three. Using SPSS, it was determined that that the relationship between accuracy and question type is not statistically significant. This was true across all question types (Tukey HSD P = .897, .897, and 1.000; LSD p = .661, .661, and 1.000 for Q1 Q2, Q3, and Q1, Q2, Q3 respectively).

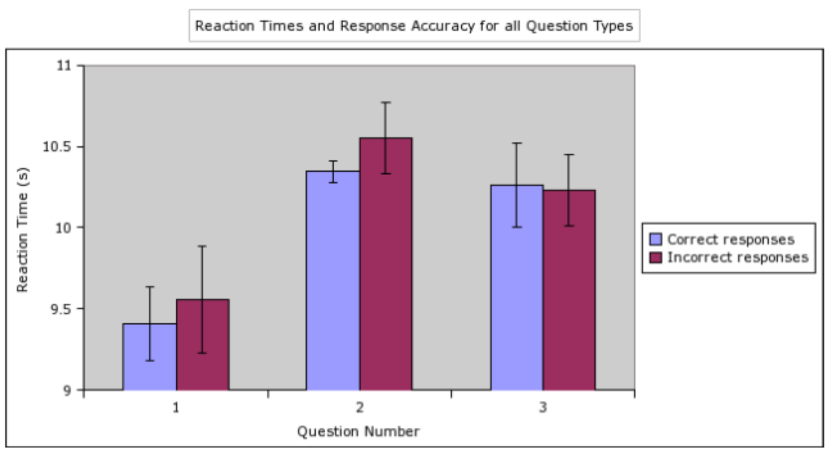


Figure 3: This figure shows the interaction between response time and accuracy across all question blocks. This data demonstrates that Questions of type one had a much faster reaction time then questions of type two and type three. Questions of type two had the slowest response followed closely by questions of type three. This data also shows that correct answers have a faster reaction time then incorrect answers.

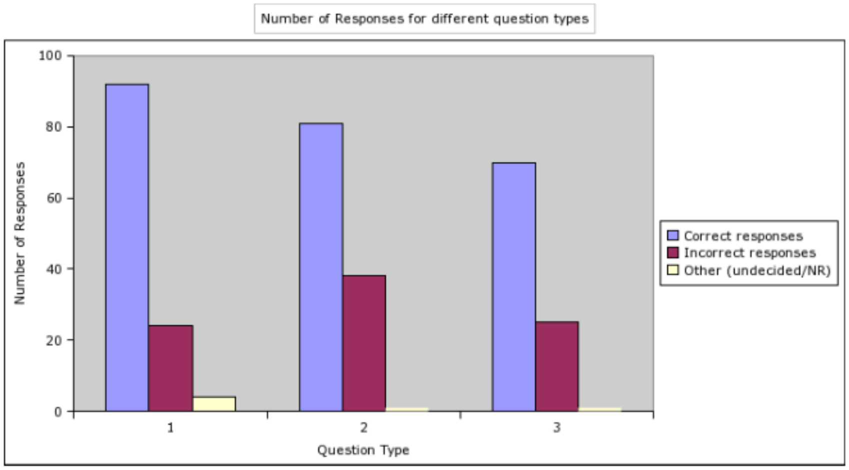


Figure 4: This figure shows the number of correct and incorrect responses per question type. These results demonstrate that correct responses were much more prevalent then incorrect responses. "Other" responses include answers where the participants or replied with both 'yes' and 'no' responses. The data indicated that questions that required a low social cognitive load had more correct answers then questions which required a higher social cognitive load. This data is skewed by the missing data in two of the question sets.

Question Type vs. Response Time

The mean reaction time for each block was 10 seconds (10.05s ± 0.6s, 10.07s ± 0.57s, and 10.03s ± 0.67s for blocks 1, 2, and 3 respectively) and the overall response time was 10.05s ± 0.60s. This gives credence to the decision to use 10 seconds as an average response time for the analysis previously conducted by Ciccia and colleagues (2006). It is also important to note that the response times did not change over the course of the study. Having the same response time over all three blocks indicates that the participants were not getting faster or slower as the study progressed. Separating the responses by question type, it becomes clear that reaction time varies by changes in social cognitive load. Specifically, the data indicates that question type ones had a faster reaction time then either questions two or three. As Figure 5 indicates, this difference in reaction time seems to be restricted to question one versus question types two and three, and there does not appear to be any difference in reaction time between questions of type two and type three.

The mean reaction time for question type ones over all blocks is 9.54s ± 0.71s. This is appreciably lower then the mean reactions times of questions of type two and three (10.32s ± 0.29s and 10.36s ± 0.18s respectively) and could mean that the actual time of response for questions of type one could be located in the scan before the one that was looked at in the group data. The differences in reaction times can be clearly seen in Figure 6. It is also of note in this figure that the first questions asked in each block have a slower reaction time then any other question type one in the study. In fact, the reaction time of this first question is often higher then those of the other question types.

The relationship between question type and response time was determined in post-hoc testing. It was determined that there was a significant difference ($p = .000$) for Question 1 as compared to questions two and questions three. No significant difference was found between response times for questions two and three (Tukey HSD $P = .951$, LSD $P = .766$).

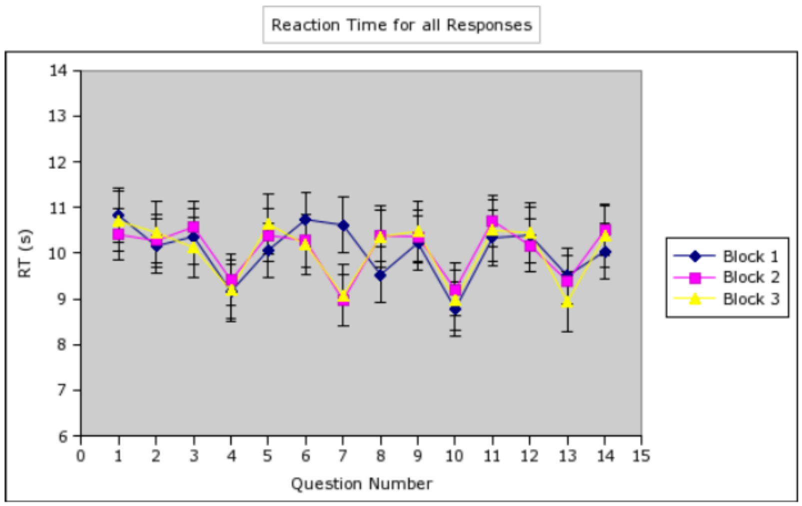


Figure 5: This graph shows the average reaction times for questions during the three blocks. This data indicates that, on average, questions of type one had a faster reaction time. This was true across all blocks. This data also indicates that questions of type two and type three similar reaction times.

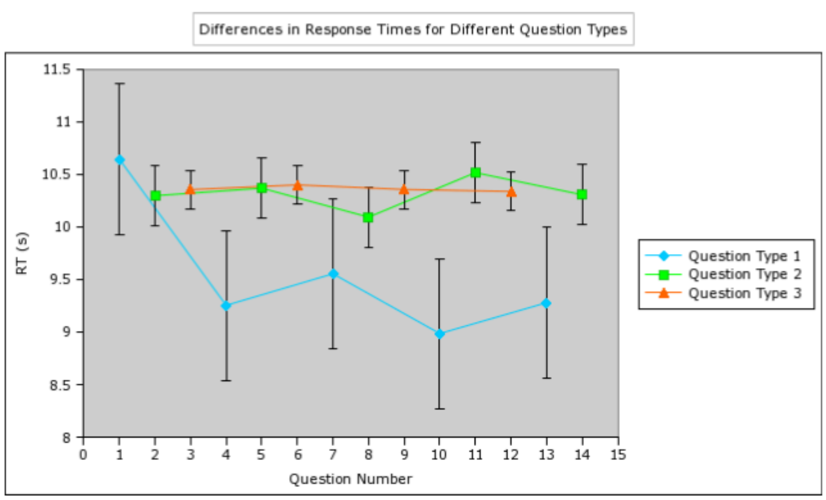


Figure 6: This figure shows the response times for different question types. Questions of type one (representing questions requiring the lowest social cognitive load) had the fastest response time of any of the questions. Questions of type two and of type three (representing moderate and high social cognitive load) have about the same reaction times.

Response Time vs. Accuracy

Further analysis of the behavioral glove response data showed that participants made correct social judgments faster then they made incorrect social judgments. The mean reaction time for correct answers was 9.97s ± 0.23s while the mean reaction time for incorrect answers was10.23s ± 0.47s. These results are shown in figure 7.

This finding demonstrates that the response time of the participant to the social stimuli was highly dependant on the participants' accuracy on the task. A t-test showed there to be a significant difference in reaction time for correct and incorrect answers, t(286), P = .000; t(87), P = .000. It is also of interest to note the differences in the variances between the correct and incorrect reaction times. While correct responses took roughly the same time across all blocks, incorrect response times had a greater variation. This is particularly clear in Figure 8. These figures are also important in that they illustrate that participants were neither getting more accurate or inaccurate as the study progressed.

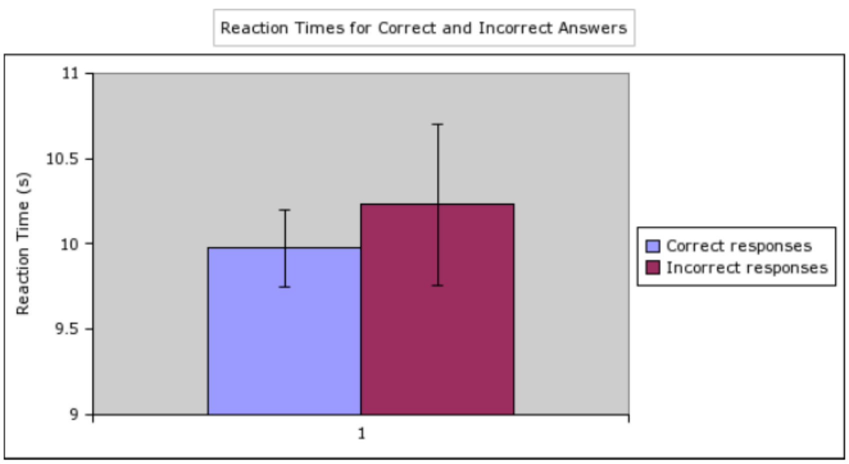
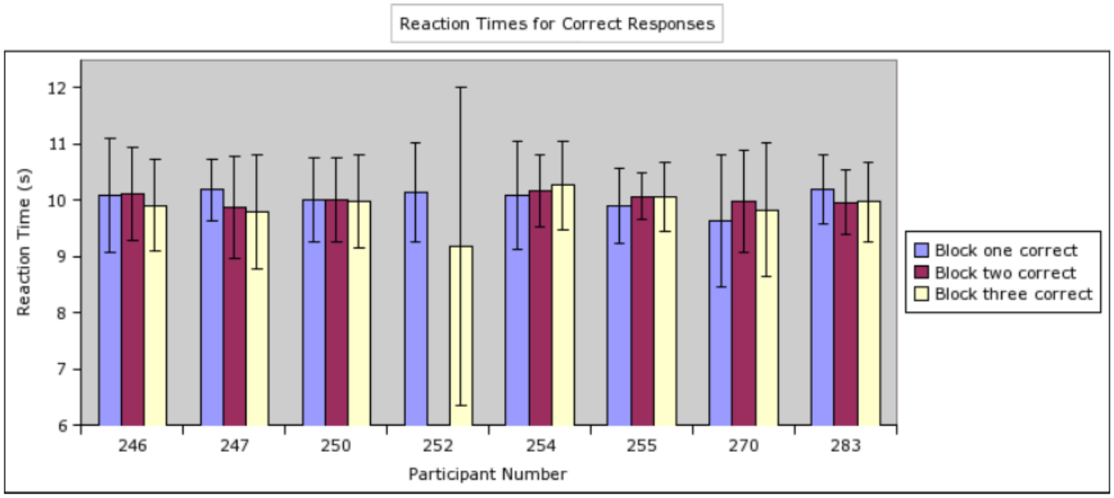


Figure 7: This figure shows the average reaction times for correct and incorrect answers. The data indicates that correct answers had a faster reaction time then the incorrect answers. The data also indicates that incorrect answers had a wider variation of responses as compared to the correct responses.

Another interesting item to note about the relationship between response time and accuracy is how it changes over time. Originally, correct and incorrect answers have about the same reaction time, with correct responses (m = 10.09s ± 0.43s) taking slightly longer then incorrect answers (m = 10.00s ± 0.68s). During the second block, the response times for correct and incorrect answers become nearly identical, with the response times of the incorrect answers (m = 10.11s ± 0.56s) increasing and the response times of the correct answers (m = 10.09s ± 0.53s) decreasing slightly. By the third block, the reaction times of the incorrect answers (m = 10.23s ± 0.41s) has continued to increase while the reaction times of the correct answers (m = 9.84s ± 0.63s) has decreased. The end result is that the response times of incorrect answers increase over time, while the reaction times of correct answers decrease over time. This data can be seen in figure 9.

Imaging Analysis

The imaging analysis previously completed by Ciccia and colleagues (2006) identified the following areas to have significant areas of activation during tasks of high social cognitive demand (represented by questions of type three) as compared to tasks of minimal so-



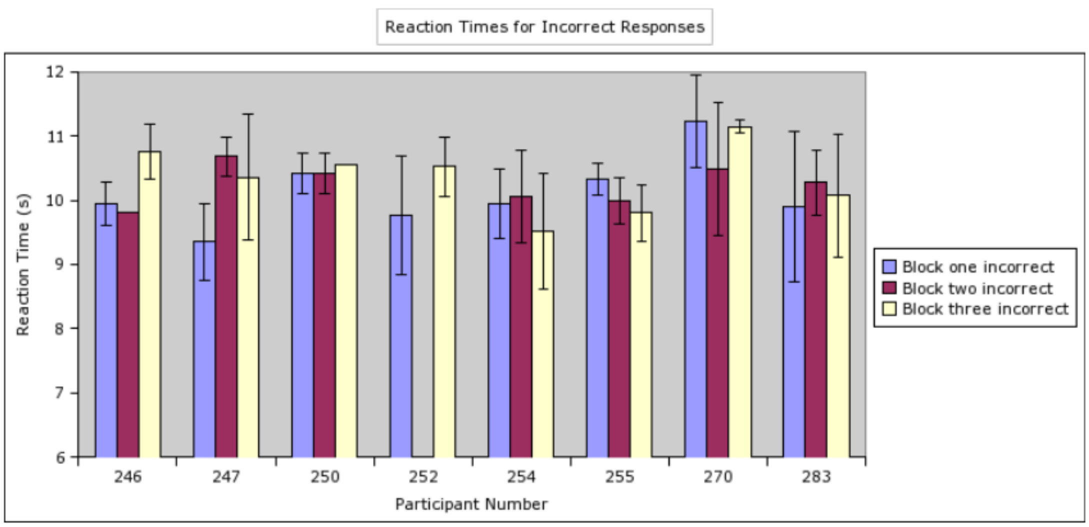


Figure 8: a) This section of the figure shows the reaction times for correct answers for all participants across all blocks. b) This section of the figure shows the reaction times for incorrect reaction times for all participants across all blocks. These figures demonstrate that correct answers had a faster reaction time then incorrect answers. The data also indicates that there was greater variability of reaction times for incorrect answers then there was for correct answers.

cial cognitive demand (represented by questions of type one) included: the left superior temporal gyrus (BA 22), the left anterior cingulated gyrus (BA 32), the left fusiform gyrus (BA 37), the right parahippocampal gyrus (BA 19), and the right inferior parietal lobule (BA 40). These results can be found in Table 1 and Figure 10.

Significant areas of activation during tasks of high social cognitive demand (represented by questions of type three) as compared to tasks of moderate cognitive demands (represented by questions of type two) include the following a priori regions: the left fusiform gyrus (BA 37), the left inferior parietal lobule (BA 40), the right anterior cingulated gyrus (BA 24), and the right inferior parietal lobule (BA 40). These results can be seen in Table 2 and Figure 11.

There were no significant areas of activation identified for the tasks of moderate social cognitive demand (represented by the questions of type two) as compared to tasks of a minimal cognitive demand (represented by questions of type one).

The imaging analysis completed for the present study yielded different results from those found by Ciccia and colleagues (2006). In the analysis for the present study, the scans representing the actual decision times were compiled and input into the SPM software. The most accurate and most inaccurate participants data were analyzed. These analyses demonstrate that there is a difference in activation between these two methodologies. Figure 12 demonstrates these drastic differences between the two methodologies.

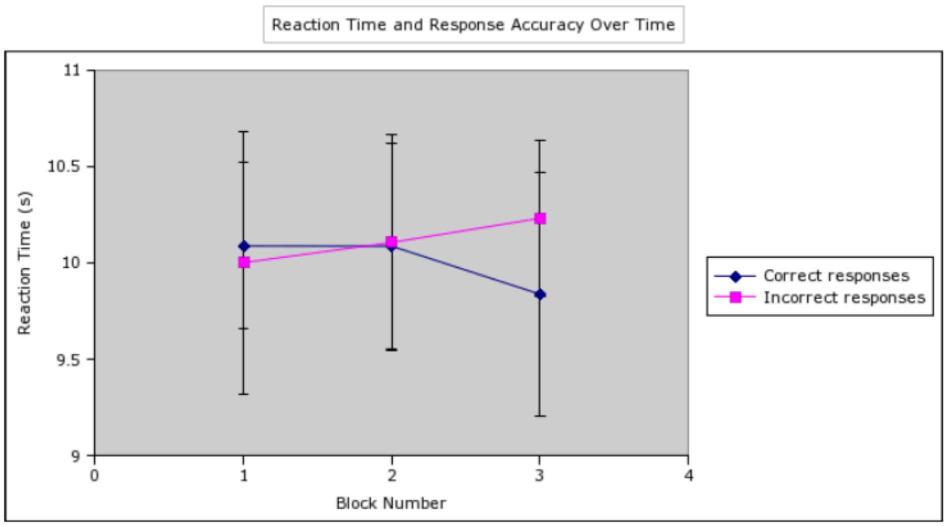


Figure 9: This figure demonstrates the reaction times of correct and incorrect answers over time (across blocks). In the first block, correct answers took slightly longer to answer then incorrect answers. In the middle block, correct answers take about the same amount of time, with incorrect answers taking slightly longer to answer. By the third block, the incorrect answers take an appreciably longer amount of time to answers then correct answers. Overall, there is an inverse relationship between reaction time and accuracy and as time goes on it takes less time for participants to answer questions correctly.

The top left image in the figure shows the results the most accurate participant, from the individual analysis using exact reaction times. The top right image shows the results for the most accurate participant from the Ciccia et al (2006) analysis. The bottom left image shows the results for the most inaccurate participant from the individual analysis using exact reaction times. The bottom right image shows the results for the most inaccurate participant from Ciccia's (2006) data. It is clear from these four images that it makes a difference whether or not the exact reaction time points are used in an imaging analysis.

Region	BA	X	Y	Z	Cluster size	T value
L superior temporal gyrus	22	-50	4	7	638	13.48
M dorsal anterior cingulate	32	-4	36	20	1282	11.19
R superior temporal gyrus/sulcus	21	**44**	-2	-10	618	9.84
R parahippocampal gyrus	19	20	-45	-6	922	8.18
L fusiform gyrus	37	-32	-45	-11	775	7.76
R inferior parietal lobule	40	61	-26	29	308	6.42

Table 1: This table shows the areas of activation during tasks of high cognitive demand as compared to tasks of low cognitive

Region	BA	X	Y	Z	Cluster size	T-value
R inferior parietal lobule	40	61	-31	37	550	14.45
R ventral anterior cingulate	24	4	34	13	3073	14.06
L fusiform gyrus	37	-30	-45	-16	6246	12.87
R insula	13	34	-14	-1	542	12.02
L superior parietal lobule	7	-30	-48	54	365	7.54

Table 2: This graph shows the areas of activation during a task of high cognitive demand as compared to tasks of low cognitive demand. These images were made using the traditional 10s time point as an average decision time.

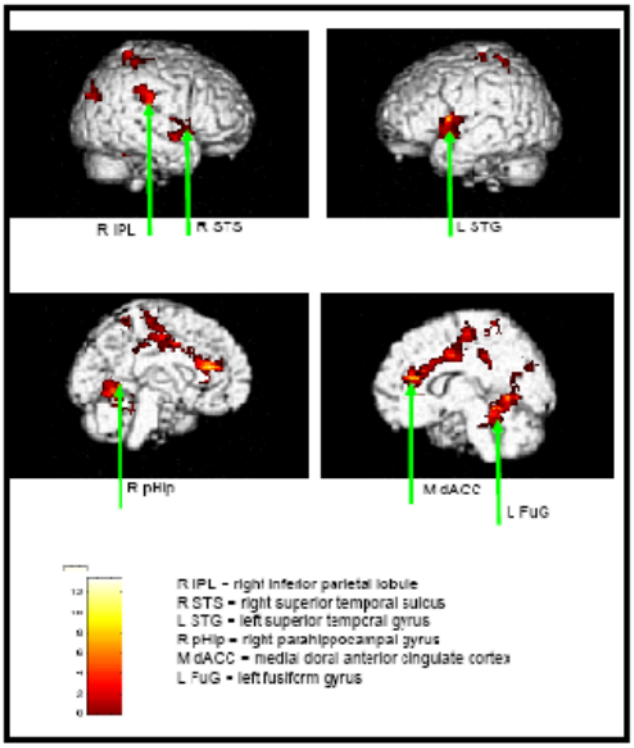


Figure 10: This figure shows the areas of activation during tasks of high social cognitive demand as compared to tasks of moderate cognitive demand. These images were m

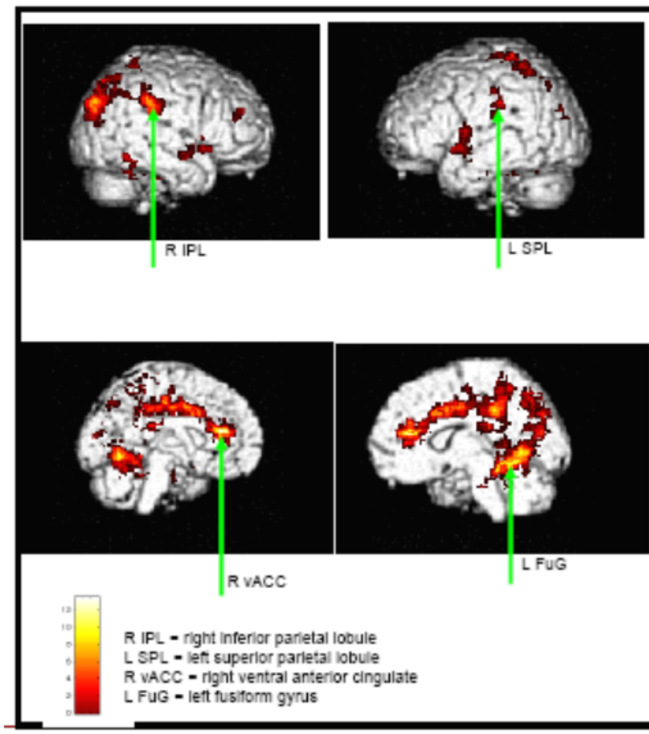


Figure 11: This graph shows the areas of activation during a task of high cognitive demand as compared to tasks of low cognitive demand. These images were made using the traditional 10s time point as an average decision time.

DISCUSSION

The results of this study supported the relationship between accuracy, reaction time and question type when analyzing behavioral responses of adolescents when making social decisions. Specifically, the analysis reveled that participants made correct social judgments faster then they made incorrect social judgments and that reaction time was significantly related to question type, with questions with lower social cognitive load taking less time than more difficult social cognitive questions.

The results of this study showed that the number of correct answers decreased over time. These decreasing correct answers could represent the effects of increasing the social cognitive load. This result may have been impacted by the loss of answers from questions of type three when question number 15 from each block from the study was lost because of a software problem with MATLAB. The results also could have been affected by missing data from all stimuli in block two from one the participants. Additionally, results may have also been skewed slightly by the difference in the number of correct versus incorrect answers. There were significantly more correct responses then there were incorrect responses. However, this result is not surprising, as this study employed a test of normal social interaction, and called upon a sample of participants with no history of social problems or deficits.

Correct responses took significantly less time to answer then incorrect responses. It is very interesting that note only did participants take a longer to answer incorrectly, but their increase in amount of time does not appear to have improved their accuracy. There are many reasons why this could have occurred. The first is that the participants either knew the answer, or they did not, right away. When they knew the answer immediately, they did not have to put any thought into generating their response. When they did not know the answer, they may have had to slowly work through the question and wound up getting it wrong regardless of their increasing in time spent considering their response. Inaccurate answers could have also taken longer because the partici-

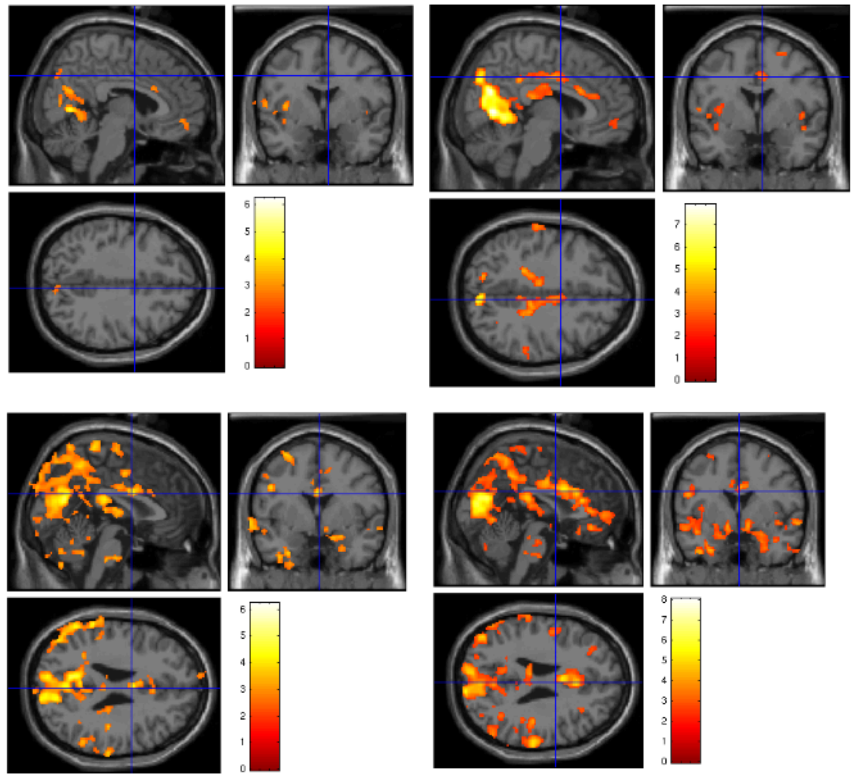


Figure 12: This figure shows the differences between the two methodologies. The images on the left were created using the exact reaction time methodology. The images on the right are those created by the original 10s method used by Ciccia and colleagues (2006). The images represent the same decisions, and should be the same if the two methods were equal. The top two images come from the most accurate participant and the bottom two images come from the most inaccurate participant.

pants were thinking about them harder. Additional analysis of the situation could lead them to both longer reaction times and incorrect answers.

Theoretically, it is not surprising that questions of type one took the shortest amount of time to answer. However, it was a surprising finding that questions of type two and type three took almost the same amount of time. The third question was hypothesized to be the most difficult in the set and required the greatest amount of cognitive load, therefore would take the longest amount of time. This was not the case. It could be that the third question was not as difficult as the researchers intended. It could also be that eventually all difficult social questions reach an asymptote and wind up taking similar amounts of time. Even though questions of type one took the least amount of time, the first question of type one in each block took the same amount of time, or longer, then questions of type two or three. It has been hypothesized that, due to the time break in-between the blocks and the practice sessions that occur between them, restarting the block means that the participants need to readjust their internal timing to the paradigm, and that results in participants taking longer to answer the first question in each block. By the second question in each block, the participants seem to readjust to making the required social judgments.

The results of the behavioral data analysis were used to analyze the functional imaging data of the most accurate and the most innacurate participants. This portion of the analysis was conducted to identify differences in patterns of brain activation when individual response patterns were used as the foundation of the analysis as opposed to a group mean reaction time. As can be seen in the data, the use of individualized response times in the imaging analysis did alter the results of the functional imaging analysis. It should be noted at this point that for the original analysis, summing the data may have produced the best results. Choosing this average decision was helpful in that is allowed researchers to average the data and to look at it as a whole, instead of looking through each individual participant. This current research demonstrates that although a standard response time can be applied as a framework to conduct the functional imaging analysis, it does not take into account the individual variation in performance, both in terms of accuracy and response time, which is important to ensure valid interpretation of imaging findings. Taken together, these results have important implications for modifications in the functional imaging paradigm used to study social cognition using Ciccia's (2006) current protocol.

It is important to note that there were many limitations in this study, including missing data for twenty-four responses to questions of type three due to problems with the response gloves. Because of the missing data, any trends that might have existed specifically for questions of type three may have been skewed. In addition to this, the responses of a singular participant to question block two had to be removed from the study due to inappropriate responses (i.e. failing to answer a question or answering both 'yes' and 'no'). Although the information with the VR gloves was accurate enough for this study, the next study will change to a button response box. The researchers believe that this will be more successful within this study for a number of reasons. The first is that a button-pressing response paradigm is more natural, and might require less training and concentration then just moving a finger. The use of the response box could lead to fewer instances of undecided (answering both yes and no) answers. The response box also allows for more rigorous accounting of reaction time. Unlike the present system, where a movement of a gloved hand causes a waveform pattern which indicates the moment of response on a continuous time scale, the button system would log the exact time of the response (reducing the time required to go to the waveform image and manually note the response time). This would give a more accurate account of response time, and, since the system is disabled after a participant responds to a question set, there would be fewer instances of undecided responses.

Although the methodology of the original study worked well, this research demonstrates that more specificity is needed when it comes to social cognitive functional imaging analysis. The next step in this study will be to do a full analysis of the imaging data taking individual reaction time and accuracy into account and using the individual analysis to conduct a group data analysis. In addition, the improvements in the current paradigm will allow for application of this paradigm with an adolescent clinical population that has know social cognitive deficits, such as Autism or Asperger's syndrome.

The results of the present study will help shape continued work in this lab in the areas of methodological improvement, in-depth comparative behavioral and imaging data analysis, consideration of developmental effects on neural activation, and applications to a variety of clinical populations with social cognitive deficits. Specifically, the lab hopes to due an individual-based functional imaging analysis on the effects of accuracy on individuals region of interest activation. The lab also plans to study inactivation in the group data as well as in the individual data.

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