Advances in Cognitive Sciences
Vol 23, No. 2, Summer 2021
Research Article
Pages 1-15

Visual attention patterns in autism spectrum disorder

Mohammad Kiani[1], Hamidreza Pouretemad[2*], Jamal Amani Rad[3]

1. PhD Candidate in Cognitive Science, Institute for Cognitive Science Studies, Tehran, Iran
2. Professor, Department of Cognitive Psychology, Institute for Cognitive and Brain Sciences, Shahid Beheshti University, Tehran, Iran
3. Assistant Professor, Department of Cognitive Modelling, Institute for Cognitive and Brain Sciences, Shahid Beheshti University, Tehran, Iran

Recieved: 9 Nov. 2020
Revised: 9 Mar. 2021
Accepted: 9 Apr. 2021

Keywords
Visual attention
Image processing
Eye tracking
Autistic Disorder

Corresponding author
Hamidreza Pouretemad, Professor, Department of Cognitive Psychology, Institute for Cognitive and Brain Sciences, Shahid Beheshti University, Tehran, Iran

Email: H-pouretemad@sbu.ac.ir

doi.org/10.30514/icss.23.2.1

Abstract

Introduction: Studies of visual attention in people with autism spectrum disorder often lead to contradictory results. These contradictory results are due to the use of assumptions, consideration of limited properties, and limitation of the type of stimuli. In this study, an attempt has been made to investigate the visual attention patterns of people with autism through a comprehensive study using eye-tracking data analysis, as well as image processing tools and models.

Methods: In this study, the eye-tracking data of 28 subjects with a mean age of eight years (range 5-12 years) were initially processed. Three hundred images of this study were then analyzed, visually segmented, labeled, and categorized based on low-level features (color, intensity, and directions), higher-level features (such as object size), and communication and social features by using models such as Itti Koch Model and image processing tools such as LabelMe. Visual attention patterns among people with autism were assessed using statistical tests.

Results: The obtained results revealed that people with autism pay less attention to parts of the images that include semantic and communicative features. On the contrary, they spend more time on the parts that contain tools and equipment. Besides, they are slower to pay attention to parts of the image that contain social features and instead spend more time paying attention to the background parts of the image that include repetitive patterns. In addition, they spend more time in each fixation in parts that lack semantic or social features.

Conclusion: The present study concluded that the main signs and symptoms of autism spectrum disorder could be observed in the visual attention patterns of people with autism, and these patterns may also be used to design an autism screening tool based on eye-tracking technology.

Citation: Kiani M, Pouretemad H, Amani Rad J. Visual attention patterns in autism spectrum disorder. Advances in Cognitive Sciences. 2021;23(2):1-15.

Extended Abstract

Introduction

Impaired social interaction and communication deficits, as well as the presence of restricted and repetitive behaviors and interests, are known as the main symptoms of autism spectrum disorder that can be seen at early ages. Infants communicate with the environment and others through their eyes. The first information containing social content is transmitted to the infant through his/her eye contact with the eyes and face of the mother and other

people. Studies have shown that this phenomenon is the background for the formation, development, and evolution of neural networks and circuits related to social relationships during human development. Some studies have shown significant differences between the eye movement patterns (saccade and fixation pattern) between people with autism and people with typical neural growth patterns. Studies of visual attention in people with autism spectrum disorder often lead to contradictory results. Some studies have found several differences in the visual attention patterns of people with autism compared to Neurotypical individuals, and some have not found any differences between the two groups. These contradictory results are due to the use of assumptions, consideration of limited properties, and limitation of the type of stimuli. In this study, an attempt has been made to investigate the visual attention patterns of people with autism through a comprehensive study by using eye-tracking data analysis, as well as image processing tools and models.

Methods

In this study, the eye-tracking data of 28 subjects with a mean age of 8 years (range 5-12 years) were initially pre-processed. Three hundred images used in this study were then analyzed, segmented, tagged, and categorized based on the low-level features (color, edges, and brightness) and higher-level features such as object size and semantic features. In this study, to decompose the images into low-level features, we used the Itti and Koch model, a model of saliency-based visual attention for a rapid scene, one of the first models presented to model the visual saliency map of human. The images were decomposed based on color, intensity, and directions, and then the visual saliency map for each image was made based on Itti and Koch model. In the second phase of this study, to decompose the images into semantic higher-level features, all the images were segmented, tagged, and categorized using the labeling tool LabelMe, a graphical image annotation tool in Python programming language environment. In this section, all objects in the images, except very small or indistinct objects, were segmented, tagged, and placed in the appropriate category or categories. Other parts of the images in the background or covered a large part of the images with the same and repetitive pattern (sky, wall) were labeled as background. The 300 images used in this research were labeled and categorized by the mentioned method with a total of 4739 objects (human, faces, emotions, animals, tables, cars, buildings). Then, based on statistical analysis methods, such as comparing the means in two independent samples, the differences in visual attention patterns in each group based on each label, category, and layer were examined.

Results

Analysis of processed data showed that, in general, people with autism have less fixations than the control group during the viewing of images. This is consistent with data that has been seen in other visual attention studies of autism. The results of data analysis indicate that people with autism spectrum disorder pay more attention to the central area of the images than people in the control group. This phenomenon can be seen in the number of fixations in central areas and distances to the center of the fixations. Center bias is seen in both groups but significantly higher in people with autism. The Itti and Koch model showed that a model based on low-level features in images could better predict visual attention patterns in the autism group. Order analysis of fixations shows a significant difference between the first fixations occurs in one of the points, which includes a social label between people with autism and the control group. In other words, people with autism are slower to pay visual attention to the social aspects of images. Data analysis of higher-level features in images shows that people with autism pay

less attention to parts of the images that include semantic and communicative features. On the contrary, they spend more time on the parts that contain tools and equipment, which is similar to the interests and hobbies of children with autism. People with autism are also slower to pay attention to parts of the image that contain social features and instead spend more time paying attention to the background parts of the images, which include repetitive patterns or uniform colors. In addition, they spend more time in each fixation in parts that lack semantic or social features.

Conclusion

The present study's results show that the main signs and symptoms of autism spectrum disorder, impaired social interaction and communication deficits, as well as the presence of restricted and repetitive behaviors and interests can be observed in the visual attention patterns of people with autism. These patterns can pave a new way for further research and studies in cognitive neuroscience. By recognizing the parts or circuits in the brain that lead to such visual patterns, we can get a better view of how these parts or circuits of the brain work in the brain of people with autism. These patterns can also be used to design a low-cost and fast autism screening tool based on eye-tracking technology. Developing computational models based on these visual patterns makes it possible to invent fast and low-cost autism screening methods based on eye-tracking tools. Finding a small number of optimized images and create an image dataset as stimuli, rather than a dataset with a large number of images, which leads to the observation of these patterns in a group of people with autism, is vital because it can produce a rapid autism spectrum disorder screening tool, and can be considered as future studies.

Ethical Considerations

Compliance with ethical guidelines

The present study consisted of data analysis, and it was approved by Institute for Cognitive Science Studies board.

Authors' contributions

Mohammad Kiani and Hamidreza Pouretemad: Conceived the presented idea and designed the experiments, Mohammad Kiani and Jamal Amani Rad: Designed the model and the computational framework, Mohammad Kiani: Carried out the implementation and performed the calculations.

Funding

This study was funded by personal funds.

Acknowledgments

We would like to thank all the people who contributed to this study, as well as the Tehran Institute for Cognitive Science Studies and Institute for Cognitive and Brain Sciences of Shahid Beheshti University, for leading this research.

Conflict of interest

The authors declare no conflicts of interest.