2D and 3D Visualization of Eye Gaze Patterns in a VR-Based Job Interview Simulator: Application in Educating Employers on the Gaze Patterns of Autistic Candidates

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Abstract. Employment of autistic individuals is strikingly low in relation to the skill level and capabilities of this population. Roughly 65% of autistic adults are either unemployed or underemployed relative to their abilities but there is increasing recognition that this number could be greatly improved through empowering autistic individuals while simultaneously providing a boost to the economy. Much of this disparity can be attributed in part to the lack of awareness and understanding among employers regarding behavior of autistic individuals during the hiring process. Most notably, the job interview—where strong eye contact is traditionally expected but can be extremely uncomfortable for autistic individuals—presents an unreasonable initial barrier to employment for many. The current work presents a data visualization dashboard that is populated with quantitative data (including eye tracking data) captured during simulated job interviews using a novel interview simulator called Career Interview Readiness in Virtual Reality (CIRVR). We conducted a brief series of case studies wherein autistic individuals who took part in a CIRVR interview and other key stakeholders provided lived experiences and qualitative insights into the most effective design and application of such data visualization dashboard. We conclude with a discussion of the role of information related to visual attention in job interviews with an emphasis on the importance of descriptive rather than prescriptive interpretation.

Keywords: Eye gaze · Autism · Inclusive employment · Job interview

1 Introduction

In the United States, the employment rate among autistic[1] adults is unacceptably low. An estimated 5.4 million autistic individuals are of working age, yet upwards of 65% remain

[1] We have chosen to use identity-first language (e.g., *autistic person*) as opposed to person-first (e.g., *person with autism*) because recent surveys of autistic self-advocates suggest a preference for identity-first language [13].

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unemployed or underemployed (i.e., employed but earning an income that is insufficient to support independence) [1]. Researchers estimate that an employed autistic adult would contribute upwards of $50,000 per year to the US economy [2], representing a staggering loss to the US gross domestic product and, far more importantly, untold societal cost from the opportunities lost by not engaging these individuals in the workforce. What accounts for this massive employment disparity? One major factor is that many autistic job candidates struggle to get past the interview phase of the job search [3]. This is often attributed to differences in social communication within this population, such as inconsistent eye contact or otherwise not engaging in "neurotypical" styles of communication [4]. Additionally, autistic individuals may give literal responses to questions that neurotypical individuals would interpret and respond to differently, leading to potential confusion on the part of the interviewer. To borrow an adapted example from [3], an employer may ask "Can you tell me about *X*?"—*X* being a placeholder for any topic—and the autistic candidate may respond simply with, "Yes" or "No" without elaborating.

Fortunately, there is now growing recognition—already quite strong among autistic self-advocates but increasingly so among employers—that simple accommodations in the workplace setting (including in job interviews) can significantly lower barriers to employment for this population [2, 3, 5]. Critically, we believe there is an opportunity to educate employers about issues related to effective and equitable approaches to interviewing autistic individuals. In this context, the current work is concerned with the characterization of visual attention patterns of autistic individuals during simulated job interviews. Our objective in this regard is to show that information about autistic individuals' visual attention (a) should be regarded as *descriptive* rather than *prescriptive*, and (b) can be meaningfully presented through visualizations and metrics that are of practical interest to autistic individuals and to other key stakeholders in the autism employment ecosystem, such as job coaches and career counselors (e.g., with colleges and universities). We emphasize here that information related to the visual attention patterns of autistic individuals is not meant in any way to change the autistic individual or to shape their gaze in the mold of their neurotypical peers. Instead, this information is made available to autistic individuals to be evaluated in any way they deem useful.

To test whether this kind of information is in fact valuable, we conducted a brief series of case studies wherein autistic individuals participated in a simulated job interview using a Virtual Reality-based job interview simulator called Career Interview Readiness in Virtual Reality (CIRVR) [6]. CIRVR is unique among tools for practicing job interviews because it combines speech-based interaction with elements of affective computing to create semi-naturalistic interview scenarios in which the virtual interviewer is "aware" of and sensitive to the interviewee's level of stress. This job interview simulator features (a) natural language-based communication between the interviewee and the virtual interviewer that is currently enabled by Microsoft Azure cloud services; (b) real-time stress detection as measured by the Empatica E4 (https://www.empatica.com/research/e4/)—a small, wrist-worn physiological sensor that measures heart rate variability and electrodermal activity; (c) eye tracking to capture visual attention patterns with current support for devices from both Tobii and Fove; (d) facial expression detection to periodically measure expressions from the set of universally-recognized emotions define in [7]; and

(e) options for immersive VR interaction as well as non-immersive, desktop-based interaction with current support for head-mounted displays from both Fove and Vive. Figure 1 presents visuals from the CIRVR system.

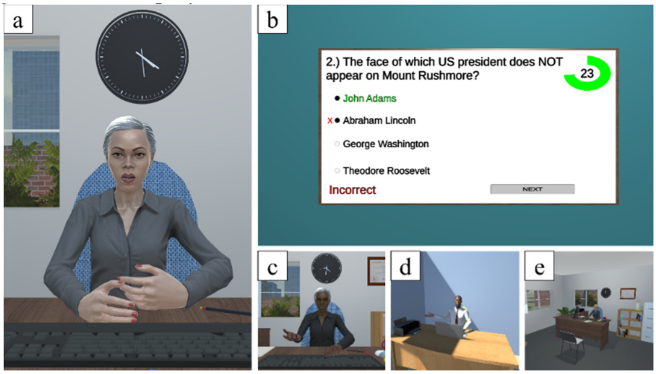

Fig. 1. Career Interview Readiness in Virtual Reality (CIRVR) job interview simulator: (a) interviewer asking a question while using contextually-relevant hand gestures and lip movements; (b) a "whiteboard" feature used to capture interviewee responses to knowledge- and experience-oriented questions; (c) another example of an interviewer avatar gesturing towards the interviewee; (d) a receptionist avatar seated in the lobby of the virtual office environment; and (e) the simple layout of the interviewer's office.

CIRVR is neither the first nor the only technology to be applied in this space. Virtual Interview Training for Transition Age Youth (VIT-TAY) was used by Smith and colleagues in a randomized controlled trial transition age autistic individuals and found evidence of reduced anxiety and improved interview performance post-training [8]. VIT-TAY is a job interview simulator comprised of highly structured, pre-recorded video clips that allow users to practice applying job interview skills. In the commercial arena, Virtual Speech is a VR product that allows users to practice soft skills such as public speaking and provides quantitative measures of progress and performance over time (https://virtualspeech.com/). HireVue is popular example of a commercial product in this space (https://www.hirevue.com/). HireVue's platform allows real-world job candidates to pre-recorded videos of themselves taking part in a job interview that is then quantitively analyzed by HireVue for candidate assessment (but, importantly, not candidate training or practice). While each of these technologies is quite innovative and has shown promise for each of its target populations, only CIRVR and its accompanying dashboard application were designed from the ground up with the singular objective of lowering barriers to employment for autistic individuals.

The remainder of the paper is organized as follows: Sect. 2 provides a brief overview of the data visualization dashboard; Sect. 3 describes the gaze data visualization methods; Sect. 4 presents the results of a small set of case studies; and Sect. 5 concludes the paper with a discussion of the results as well as planned future work.

2 Data Visualization Dashboard

Here we describe the data visualization dashboard that accompanies CIRVR, our novel job interview simulator. While this paper focuses on metrics pertaining to the interviewee's visual attention patterns, the dashboard prototype also features a range of other visualizations and tables related to the interviewee's spoken responses and experienced stress. Validation of these latter features remains part of ongoing work and are not discussed here.

The data visualization dashboard is a React.js web application that houses an array of components, each of which communicates a unique aspect of the interviewee's experience using the CIRVR system. A sampling of these components is given in Fig. 2. Currently, the data presented characterize several signals including physiological and self-reported stress, facial expressions (neutral, happy, surprise, sad, angry, fear, contempt, disgust), speech (from both the interviewee and interviewer), and eye gaze. A variety of interactive visualization methods are used, including time series graphs, scatter plots, heat maps, and tables. The dashboard and CIRVR were each developed with the direct involvement of autistic individuals to maximize the agency and participation of autistic people through inclusive design practices. This involvement included, for example, design decisions at the conceptual level, software implementation, and months of iterative feedback through beta testing and in-depth discussion.

The major aims of the dashboard application and research are two-fold. The first is to provide quantitative information to autistic individuals and support personnel (e.g., job coaches) that could provide insights into, for example, more effective management of anxiety in relation to challenging questions. An autistic user, for example, may be interested in knowing how their visual attention patterns changed during the course of the interview, perhaps due to uncomfortable eye contact or after an ambiguous prompt such as "Tell me about yourself." Likewise, a job coach could identify interview questions that resulted in the greatest stress responses in order to share strategies for managing stress when encountering similar questions in the future. The second major aim is to provide insights to employers about the types of interview questions that do and do not work well in understanding the skills and qualifications of autistic individuals.

Direct and consistent eye contact during a job interview has been traditionally regarded as evidence of a candidate's strength, but eye contact can be quite uncomfortable for many autistic individuals [3]. We reiterate that the visual attention information captured by the eye tracker is *not* designed to prescribe patterns of visual attention such as extending the amount of eye contact demonstrated by the interviewee. Rather, this information is hypothesized to be valuable in and of itself as a means of understanding one's own behavior and our hope is that this work raises the level of awareness of employers that, although some autistic individuals may not make consistent eye contact, this should not be taken to mean that she/he is not paying attention or is any less qualified.

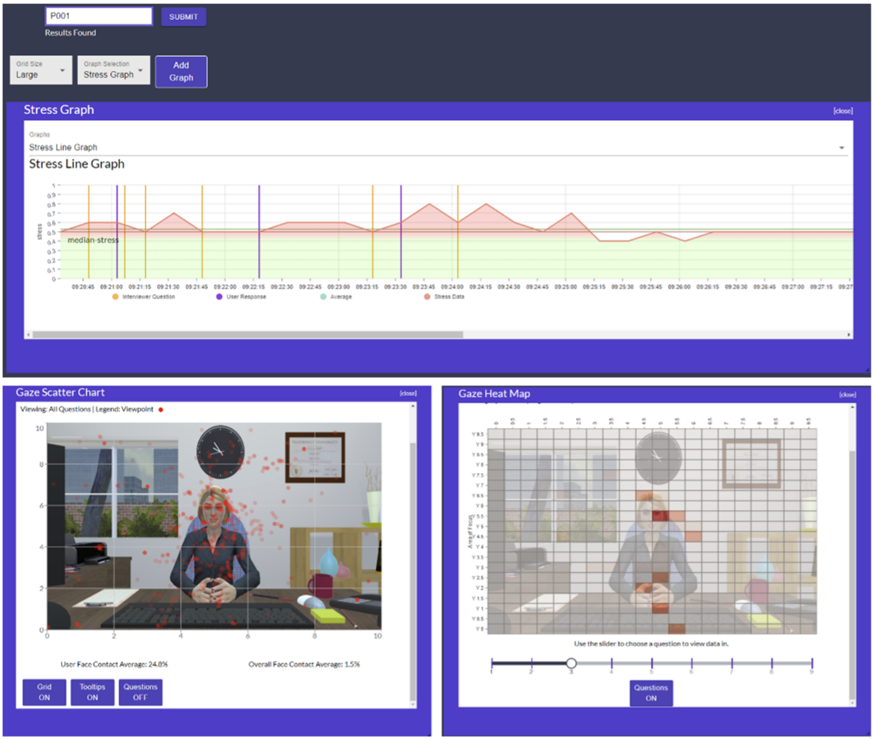

Fig. 2. Example components from the data visualization dashboard: (top) time series plot of stress signal with respect to event markers such as questions and response, (bottom left) a scatter plot of the interviewee's gaze data, and (bottom right) a heatmap-style presentation of the interviewee's gaze data.

3 Visualization Methods

Data collected from the simulated interviews were de-identified and recorded in a SQL database accessible to the dashboard application. The database schema was designed in such a way that the table containing eye tracker data was agnostic to the particular eye tracking device used to collect this data. This allowed the dashboard to query gaze data and to populate 2D or 3D visualizations in a uniform way using any of the supported devices, which, at the time of this writing, includes devices from manufacturers including Tobii, Fove, and Vive. By "2D visualizations," we refer to the non-immersive condition in which the user interacts with CIRVR using a keyboard, mouse, and monitor with a remote eye tracker such as the Tobii X3-120. By "3D visualizations," we refer to the immersive VR condition in which the user interacts with CIRVR using a head-mounted display system with embedded eye tracker, such as the Fove or Vive Eye.

Support for a 3D condition was pursued as a system feature because evidence in other contexts supports an association between increased naturalism/immersion and ecological validity [9]. However, tolerance of head-mounted displays is not universal and must be considered on an individual basis as some people respond negatively to immersive VR experiences. As such, the 2D condition was essential to be inclusive of individuals who would not tolerate the 3D experience. That being said, there is some evidence to support that autistic individuals may generally tolerate immersive VR experiences well and, in fact, may find these experiences quite enjoyable [10].

3.1 2D Visualizations

Gaze data captured while the user takes part in the non-immersive version of the simulated interview were obtained using the Tobii 4C, which has a sampling frequency of 90 Hz, a tracking accuracy $<1°$, and an operating distance between 50 and 95 cm. As these data are recorded, fixations are computed in real-time based on a moving window analysis coupled with a hybrid velocity- and dispersion-based algorithm adapted from [11]. The adaptation simply extends the velocity-based threshold algorithm by introducing statistical parameters to characterize fixations in the context of the simulated interview. Using a moving window conservatively set at 150 ms in length (or roughly 14 samples) [12], we tracked the change in velocity of points within the window in the first pass, then in the second pass these velocities are compared against a threshold, and if the change in velocity is sufficiently small, then the window is labeled as a probable fixation. As fixations are found, they are subsequently recorded in a csv (comma-separated values) file following the format *fixation centroid X, fixation centroid Y, fixation radius, fixation onset time, and fixation offset time,* followed by a list of the names of objects intersecting with the fixation point in the virtual environment (e.g., the virtual interviewer, the clock on the wall, etc.).

After a user has completed a simulated interview and their fixation data have been collected and stored in the SQL database, the data can then be retrieved via their anonymized PID (Participant ID) in the dashboard application. Once retrieved, a user interacting with the dashboard can view the visualized fixation data as either a scatter plot of fixations or as a heatmap of quantized regions within the interviewee's field of view (see Fig. 3). For the scatter plot, made using the provided scatter plot in the Recharts library (https://recharts.org/), the provided fixation points are plotted based on the fixation positions with radii proportional to the fixation duration. The points are placed against a still image representative of what the user would have seen during the simulated interview. For the heatmap, we used the heatmap implementation from Nivo (https://nivo.rocks/heatmap/) and specified the color intensity of individual cells based on the frequency of fixations that intersect them, the color being based on a grey-red gradient where grey corresponds to low fixations and red corresponds to many fixations. For both visualization approaches, a user interacting with the dashboard can view the data over a variety of intervals, including the entire interview or on a question-by-question basis.

3.2 3D Visualizations

Gaze data captured while the user takes part in the immersive VR version of the simulated interview were obtained using the Fove head-mounted display, which has a sampling frequency of 120 Hz and a median tracking accuracy of 1.15°. To capture the location of the participant's gaze, the Fove utilizes Unity's built-in raycasting system, which essentially calculates the intersection(s) of a ray cast in the direction of the user's gaze

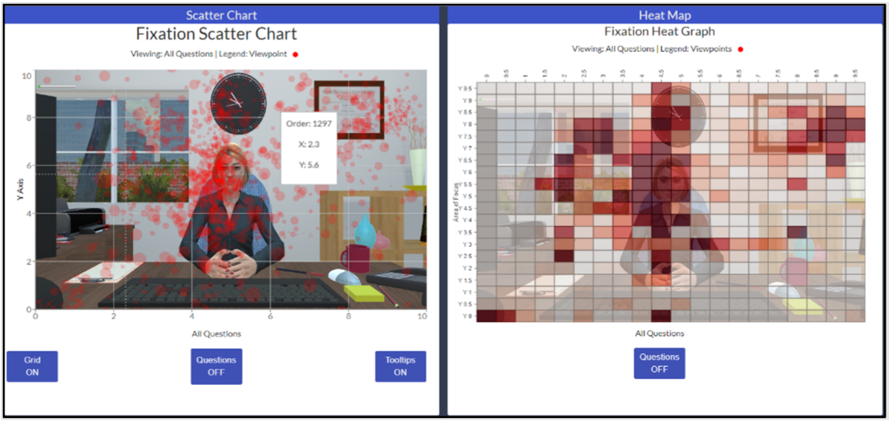

Fig. 3. The 2D approach to gaze data visualization: (left) scatter plot of fixations with radii proportional to their fixation durations and (right) gaze heatmap for quantized regions relative to the interviewee's field of view.

with one or more objects in the path of the ray. To record the times series gaze data from the Fove in this manner, both the direction of the ray, and the origin point in 3D space of the ray were recorded. This information, along with timestamps and the names of viewed objects, were written to the csv files and later transferred to the SQL database.

Once these data are collected in the database, they can then be retrieved and displayed using a Unity WebGL build and a WebGL player component separate from the dashboard itself (in the future, we aim to embed the WebGL player directly in the dashboard application). In the WebGL player, the user can select from among four different 3D visualization methods (see Fig. 4). In each method, a ray is cast from the origin point of the interviewee's eyes in 3D space in the direction of the interviewee's gaze at that point in time. When a ray collides with another object in the scene, that is the point in space where we predict the interviewee's gaze ultimately landed. After all of these points in space have been predicted, we are finally able to plot the points accordingly. The first 3D visualization method simply displays a green sphere that moves over time in relation to the previously noted raycast collision predictions (Fig. 4a). The other visualization methods present variations on this theme (Fig. 4b, 4c, and 4d). With these methods, the dashboard user can choose to view fixation data plotted sequentially (as if by playback in real time) as well as presented as a complete distribution all at once. In the case of the latter, the sequential portion is displayed in green while the static components are presented in a contrasting color.

4 Case Studies

We hypothesized that (a) capture of both 2D and 3D gaze data within CIRVR would be feasible and suitable for visualization within the dashboard tool; (b) autistic individuals and other key stakeholders would find initial value in the visual attention components of the dashboard; and (c) qualitative feedback from autistic individuals and other key

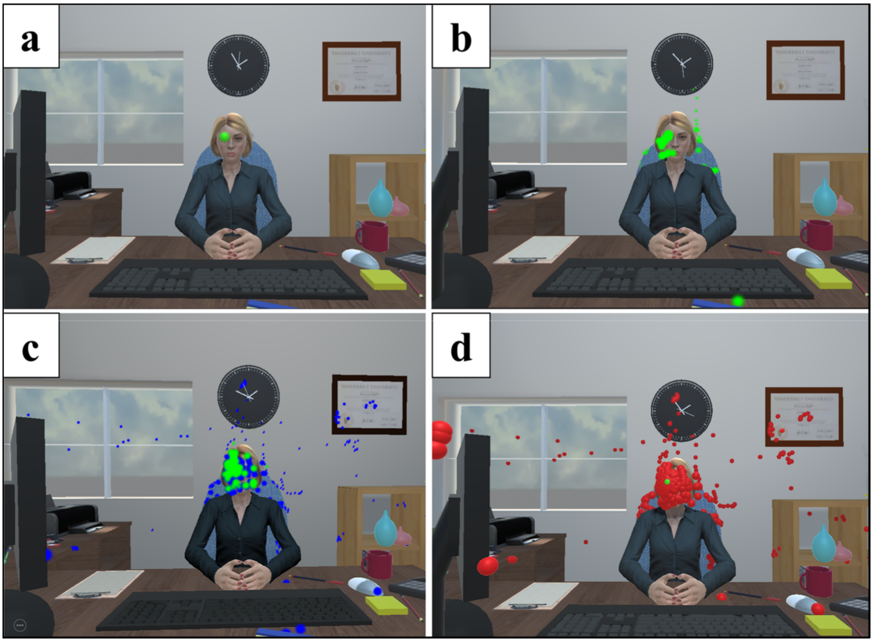

Fig. 4. 3D visualization of fixation data: (a) real-time playback of scan paths; (b) real-time playback of scan paths overlaid onto entire distribution of fixations shown as flattened objects; (c) simple real-time playback of current fixation; and (d) real-time playback of scan paths overlaid onto entire distribution of fixations shown as spheres. (Color figure online)

stakeholders would reveal new insights with respect to more effective and valuable ways to present information about visual attention. To test each of these hypotheses, we conducted a small series of case studies with individuals from each of these target groups as described below. The research was approved by the Institutional Review Board (IRB) at Vanderbilt University and all participants provided informed consent or assent in accordance with the requirements set forth by the IRB. Personnel conducting the sessions had several years of experience performing human subjects research involving autistic individuals and were well-equipped to address accommodations that might have arisen during the sessions. Autistic participants were compensated for their time and travel to take part in the simulated interview. Employer participants were not compensated for their time and did not travel to take part in the study.

4.1 Feedback from Autistic Individuals

Four autistic individuals took part in the study. The reader should note that two of these individuals were also involved in the development of the dashboard application and are co-authors of this work but had not previously taken part in a simulated interview using CIRVR. As such, all of the received feedback is regarded as valid within the scope of the testing performed for the current stage of qualitative evaluation of the technology. Autistic participants were invited to take part in a roughly one-hour session in the university laboratory. Due to the COVID-19 pandemic, appropriate precautions were taken to ensure the safety of both the participants and researchers[2]. After providing consent/assent, the participants completed an approximately 20-minute simulated interview using the CIRVR system. All participants experienced the non-immersive implementation of CIRVR, and the two participants form the development team also experienced the immersive implementation of CIRVR while wearing the Fove head-mounted display. After the simulated interview portion of the study, a researcher and the participant engaged in a brief qualitative interview to discuss the user's experience with the system as well what kinds of information the participant might like to see and learn from based on their experience. All participants completed the study without any adverse events or loss of eye tracker data.

Following the simulated interview using CIRVR, participants were asked to share their thoughts about their experiences and about the potential benefit of seeing the data extracted during the simulated interview. Participants reported largely positive experiences overall, only citing some sections of the interviews as eliciting stress, with some noting a particular interest in seeing how much eye contact they made with the virtual interviewer. Another participant said that he would like to see a general review of his interview performance but was not interested in the eye tracking data. Cumulatively, the data collection and feedback support the hypotheses that data collection of this kind is feasible and that data regarding visual attention during simulated interviews may be of value to some, but perhaps not all, autistic individuals.

4.2 Feedback from Employers

Three representatives from two different corporations (one a small business and the other a major technology company, which we will refer to as Company A and Company B, respectively) participated in in-depth, qualitative discussions about the dashboard tool and the proposed visualizations of visual attention information. Both organizations had active hiring initiatives for neurodiverse[3] and autistic talent with strong endorsement of neurodiversity within the workplace. Participant interactions were accomplished entirely remotely using video conferencing software. Audio of the conversations were recorded with the consent of the participants and then transcribed automatically using the Otter transcription service (https://otter.ai/) for offline qualitative analysis.

After initial formalities at the start of the video calls, participants were shown a brief (i.e., ~5 min) introduction to the full employer dashboard via screenshare, during which time each visualization component was described in some detail. Anonymized data were shown for some of the participants in the study as well for one neurotypical member of the development team. Data were also presented for both immersive and non-immersive VR conditions. After viewing the data, participants were asked questions from a predefined list of questions and were also invited to provide open-ended feedback of their own. The discussions covered all of the dashboard components, but we focus here on the feedback concerning the visual attention-related visualizations.

[2] Precautions related to COVID-19 included a symptom pre-screening 24 h before the scheduled session, follow-up symptom prescreening the day of the session, mandatory face coverings, and minimum 6-feet social distancing at all times during the sessions.

[3] See [2] for a definition of neurodiversity.

Two individuals from Company A provided feedback about the dashboard, both of whom served in administrative positions at the organization but regularly engaged in activities related to job coaching with autistic and other neurodiverse individuals. Feedback from these participants tended to focus on topics related to equitable employment practices in relation to the value of eye tracking information. On the subject of eye contact, one of the participants noted that "some people just can't do it, and … that's up to the employer, not to the candidate to have to make that eye contact or even worry about it. The employer needs to know that [eye contact] has no bearing at all on the interview." Building on this, the other participant added that "if you showed some of these results to someone you know, who has gone through the simulation, it's less a matter of you need to do this, you need to that [but instead] making them aware that these are the behaviors and therefore, in an interview situation, you also may have to self-advocate for yourself." Continuing down this line, the first participant added "that's why I was like, so excited … that you're also educating the employers, because that's where I think—it's not on our folks—it's the employer who needs to be educated."

A hiring manager from Company B provided feedback. When asked about the potential utility of the gaze data visualizations, this participant noted that the 2D and 3D fixation data might be particularly useful for a job coach to review but might also be useful for a hiring manager if "there are specific insights that you can feed [to] the hiring manager." Following this point, the participant further suggested that a variety of distinct *user views* might be helpful (i.e., the interviewee view, the job coach view, etc.) and that the order of content presentation on the web page might be accordingly tailored to the particular view. Another general point of feedback was that a "less is more" strategy regarding data presentation may be most effective and that "simplifying towards different [user] roles and what they need to see" could improve the utility of the presented information. Additionally, Company B also noted opportunities to enhance the accessibility of the dashboard through simple user interface modifications.

5 Discussion and Conclusion

Cumulatively, the feedback from autistic individuals and stakeholders largely supported our hypotheses, but with some important nuances. First, we successfully demonstrated that gaze data could be feasibly captured and then visualized in a meaningful way using both immersive VR (3D) and non-immersive (2D) conditions. In the future, we will continue to refine this strategy and will integrate the 3D visualization directly into the React.js web application.

Second, we learned from autistic individuals and job coaches about aspects of the gaze data visualizations that were seen as practical for review. Some of the autistic individuals expressed interest in being able to review gaze data collected during the simulated interviews in order to analyze things like the proportion of eye contact that she/he made with the virtual interviewer. However, some autistic individuals were not particularly interested in being able to review their gaze data. As such, this feature could be regarded as optional in a final version of the tool (i.e., the feature could be enabled or disabled based on the preferences of the individual). The job coaches that we heard from echoed the potential value of being able to review such gaze data with autistic individuals. Importantly, the job coaches also confirmed that a measure of eye contact should not be communicated to the interviewee in the context of changing patterns of visual attention. Finally, we learned from a hiring manager about some ways in which the dashboard could be extended to present information tailored to the type of dashboard user (e.g., interviewee or job coach) and that additional insights may actually emerge from less complex presentation strategies, such as relating changes in visual attention to the real-time stress measurement. This individual also emphasized that, in general, our future work should focus on identifying key insights that can be presented to each type of dashboard users without overwhelming the users with an overabundance of data.

Noted areas of improvement for the current dashboard application include a need to strike a greater balance between raw data and clear insights, the addition of user roles (e.g., interviewee, job coach) in which information is optimally presented for that particular role, and generally improved accessibility (e.g., optimal color schemes and extending the visual presentation to include other modalities for individuals with visual impairment). Additionally, because of the amount of gaze data being presented, the dashboard can sometimes take nearly 10 s to fully load and prepare all the data. Future work should seek to optimize gaze data queries by, for example, transitioning to a time series database solution such as InfluxDB.

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