Designing Tools To Improve Collaborative Interaction in a VR Environment for Teaching Geosciences Interpretation

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ABSTRACT

We discuss practical and theoretical solutions to problems that arose during the development of a collaborative VR application in which a teacher guides students through visualization and interactive interpretation of a geological dataset. To provide access to a large number of tools, we introduced a dashboard-style menu that rotates and moves to follow the user through the environment. We expect users to need good awareness of each other in the virtual environment, and especially to understand each other's attention to specific terrain surface features or annotations. For this, we display an eye gaze cue on the visualized terrain and visually tether a nametag widget on the dashboard to each user's avatar. Results of an initial usability review, involving an expert geologist guiding students, show promise for sharing eye gaze with a gaze trail as a basic method for understanding attention. Other tested indicators of avatar location or view appeared less important during the terrain feature presentation and interpretation. We additionally summarize ongoing work to enhance collaborative awareness through other eye tracking metrics and physiological data.

CCS CONCEPTS

• **Human-centered computing** → **Virtual reality**; *User interface design.*

KEYWORDS

virtual reality, collaboration, collaborativce VR, education, menu interaction, eye tracking, eye gaze, geological visualization

1 INTRODUCTION

The progression of low-cost VR displays with enhanced sensing (such as eye tracking in the HTC Vive Eye) makes it appealing to explore everyday contexts, such as VR-based education, with techniques that use the sensors to increase awareness between users in multi-user VR. As the devices become more available to schools, we expect teachers to show more interest in VR applications that will allow them to teach and interact with their students. VR researchers are increasingly focused on solving problems related to everyday environments, such as creating universal accessible interfaces [1], aiding in visual guidance in exploratory environments [31], and many others [12, 14].

We are investigating problems for educational VR applications for VR-non-experts. In this paper, we present approaches developed to address problems that arose during development of a geological dataset interpretation system and its use to explain datasets from the Chicxulub Impact Crater (seen in Figure 1). In the application, extending prior work [3], teachers can guide students through discussions that include interactive annotation and interpretation of data. The application visualizes terrain-like surfaces above which users navigate and change scale, view, and visualization options to study topography, gravity, and magnetic data. Interactive annotation tools allow placing markers and drawing on a surface to help users point out features to each other. Other interactions include movement, saving and loading, and switching terrain types. Whereas our early work focused on remote guidance of an audience using asymmetric displays (fishtank-to-projection [3] or TV-to-headset [10]), here we focus on networked multi-user VR with headsets and wands.

Figure 1: A teacher and student meeting in the terrain visualization environment.

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To test our solutions' viability and receive feedback, we performed a small usability study with a geology professor and four students. The study involved the professor guiding students through a discussion of the environment with a proctor asking them to perform certain tasks that emphasized the collaborative work. Participants gave feedback by thinking aloud while performing tasks and rating items like usefulness and usability after each session.

Results have inspired new features we are developing to use more eye tracking features and other sensors such as wristband-based physiological sensors. These features aim to further enhance awareness about students and collaborators, such as attentive state, understanding of the material, and stress levels, especially by presenting information to teachers when there are potential problems (for example, signs of motion sickness).

2 REQUIREMENTS ANALYSIS

We identified two major challenges during development of the system: a need for enhanced communication between users and a need for an easy-to-use interface integrating several system control features. For this application, and educational applications in general, we consider good communication between student and teacher to be essential for proper understanding of the dataset interpretation process [2, 23]. In early versions, we determined that voice chat and sharing users' wand information was not always sufficient, leaving users unsure of others locations or attention levels.

One concern from early tests was an inability to quickly determine where another user was, because the terrain could be very large. This would result in a student losing the teacher, potentially reducing understanding and degrading collaboration. To address this, we investigated methods for locating objects in 3D space. Several works have addressed the problem of users finding offscreen or faraway targets in a 2D context, but less attention has been paid to the problem in 3D virtual worlds [28]. Visual cues in 3D space often place an indicator, such as an arrow, on the periphery of the user's view to guide them to the desired object [27, 33], emphasize the desired object, or de-emphasize the environment surrounding the desired object [9]. Auditory displays have also been used to guide users toward objects, with a combination of 3D audio cues and special tones used to direct users' attention [19].

We consider that there may be multiple remote users, so the system may need to display multiple cues at once without imposing too much cognitive load for understanding cues. The educational context suggests that cues should be subtle, with users being able to focus on the content and environment for the majority of the time. To meet these needs, we developed a visual tether that followed a marker near the user to the remote user's avatar representation, that would fade in opacity when looking near that user.

Another concern regarding communication was for teachers and students to maintain a clear sense of where others are looking, to support discussions about data surface features. Sharing eye gaze has been shown to be effective at enhancing communication in collaborative applications [34]. Eye gaze is often shared through simple representations such as gaze cursors [5] and trails [25] or more complex renderings such as heat maps or discs [26].

Considering the potential for many students, we want each user's gaze representation to be minimally obstructive. To address this, we developed a gaze trail with a small spherical cursor that follows remote users' gaze on the dataset for a brief period of time. Because students may want to look at the teacher's avatar instead of constantly watching the dataset, students should still be able to know what a teacher is looking at when looking at their avatar. To meet this need, we developed a "remote view indicator" that hovers near the remote user's avatar which shows a 2D rendering of the environment from the remote user's perspective.

Systems that allow users to perform a large number of tasks often use a menu to support tool selection and to avoid confusing button mapping and context switching [7]. A robust geological dataset tool needs to provide options for annotating the dataset, moving through the environment, saving and loading, and more. Some geosciences VR tools, such as GeoZUI3D [32], included specialized world-embedded 3D widgets that each perform a certain task. More common VR menus involve placing a static menu somewhere in the environment or having the menu be centered on an object that tracks the hand position [7].

In our application, the areas of interest are primarily below the user, and we consider that users will want the data to be as unobstructed as possible. An ideal menu would be out of central view when not needed, and should be able to hold a large number of tools. To meet these needs, we developed a dashboard-style system that follows and rotates with the user to persist above the horizon, allowing them to look up to change tools at any time.

3 INTERFACE DETAILS

3.1 Dashboard and Feature Controls

Our initial menu design was a static menu that would be summoned to a desired position in the world with a button press, then removed and recreated at will. However, early tests showed that users would place the menu once and never move it, moving themselves back to the menu instead. Or, they would place the menu and lose it in the environment, even after being reminded that they could move the menu. Thus, we considered that a persistent menu that is always near the user would be best.

We settled on the "dashboard" design in which interactable widgets representing different tools would be placed in front of the user and could be moved to be arranged to the user's liking. Because we expect the user to frequently rotate their body while exploring the environment, we keep the tools in front of the user by defining an angular user movement threshold beyond which the menu rotates to follow the user. Because the areas of interest tends to be below the user, we only rotate around a vertical axis, keeping the terrain unobscured. The effect is that the user can look down at the environment for as long as they need, look up to find the menu, and it will always be in front of them.

Because we noted movement type was changed often, we provided a secondary movement selector (seen in Figure 2) to prevent the user from having to look up from the terrain to change movement type. When the user looks near their controller, it displays symbols for different movement types arranged in a column above the analog stick or trackpad. The user can then use the stick or trackpad to scroll through different movement types, with the current selected type being highlighted directly above the controller model. Because movement and scrolling are performed with the same input device (a thumbstick or trackpad), the movement action engages only when the user looks away from the controller or the controller moves away from the focus area. An icon for the active movement type is displayed near the controller to confirm and remind the user about the active movement type. The user can use this secondary movement selector to change movement without having to shift their focus too far from the terrain.

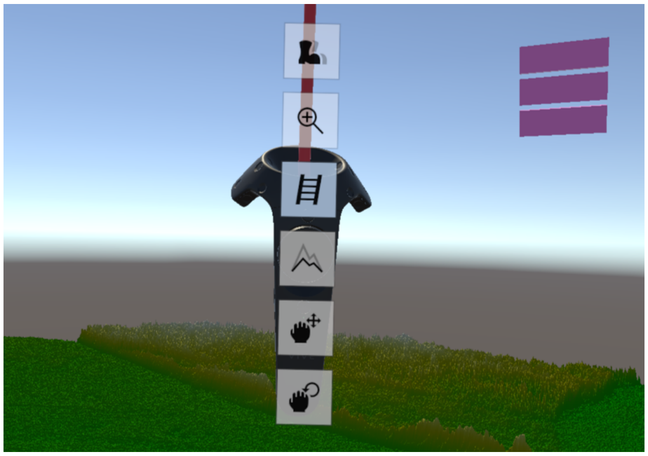

Figure 2: The controller-based movement selection menu. The icons expand when the controller is looked at and can be cycled through by tapping the trackpad.

3.2 Collaborative Tools

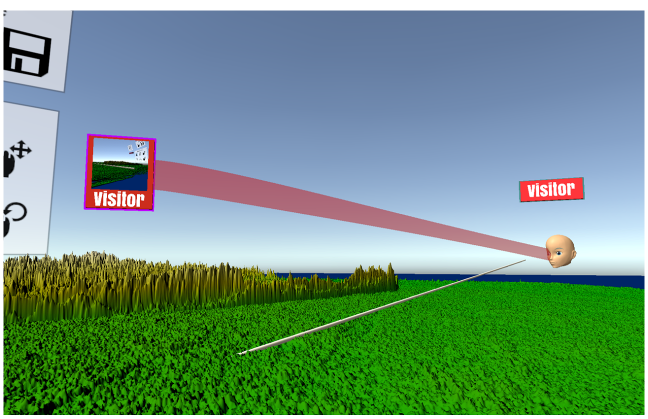

Figure 3: The tether connects the remote user's avatar to a nearby nametag that displays a remote-view indicator.

We developed two main tools to help users stay more aware of each other: a tether and a gaze trail. In the early version of the application, remote users were represented by an avatar consisting of a head-tracked head model and a hand-tracked long, thin wand that extended out to intersect the terrain. While it was possible to see someone's terrain interactions by following their wand motion, this provided limited insight into their location or intent.

The tether (seen in Figure 3) was added to allow users to quickly find each other when they are far away from each other. An earlier solution for this was to place a "nametag" above remote users' avatar heads that grows as the user gets farther away so as to always be visible when looked at. However, users still could have trouble rotating into the correct position to find the nametag.

The tether remedies this problem by connecting remote users' avatars with an arced line strip to a nametag that appears as a widget on the dashboard, and another that sits on a ring around their feet. The line strip is rendered along a cubic Hermite curve with the nametag and head as endpoints, similar to a visual guidance effect described by Yoshimura et al. [33]. This creates a tethering effect conceptually related to view tethering described by Plumlee et al. [24]. The tether changes opacity based on euclidean distance from the local to remote user, and angular distance from the local user's gaze direction to the direction to the remote user, so as to be non-intrusive when the users are not separated.

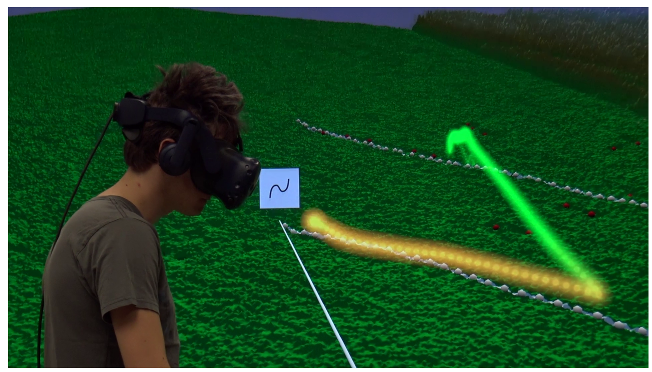

Figure 4: A user views another user's eye gaze trail to know that they are properly following an annotation line. An icon on a ray signifies the currently-active annotation tool.

The eye gaze trail (Figure 4) was added to allow users to know what the other users are paying attention to; e.g. for a teacher to know that a student is paying attention or a student to know what a teacher is talking about. An early solution, before the system supported eye-tracked HMDs, was to place remote-view indicators on all remote users' nametags to show the environment from that user's perspective. While this was somewhat effective at giving a general area that the user was looking at, the granularity of this gaze information was coarse, and a student trying to follow a teacher would need to frequently switch between looking at the environment and the nametag. Additionally, early feedback indicated that the space needed for the nametags to display the content clearly made them obtrusive.

The gaze trail solves this problem using eye tracker data from each users' headset to determine what part of the terrain they are looking at. A trail is rendered as a particle effect with a particle emitter moving to an updated terrain gaze coordinate per frame. The particles reduce in size and opacity and change from orange to green over five seconds to help the viewer know a brief history of where the user looked. This trail effect, as opposed to a single point, helps the user understand if there is a gaze pattern, e.g. looking

Table 1: Responses from questions given to the professor (P) and students (S1-4) rated from 1 to 7. A 7 given for importance represents great importance; a 7 given for ease represents very easy. Full question text is discussed in the section.

	P	S1	S2	S3	S4
Q1: Importance of Awareness	4	6	5	2	6
Q2: Ease of Awareness	7	7	6	7	7
Q3: Ease of Attention	7	7	7	7	7
Q4: Ease of Finding Tools	6	6	6	7	6

along a geographic feature. The effect is similar to the one studied by Yitoshee et al. [26], who found the gaze trail to be the highest subjectively ranked among several visualizations for sharing eye gaze. The local user's effect was not rendered in their environment, only showing that of remote users, for better clarity.

4 INFORMAL STUDY AND USER FEEDBACK

Feedback for these tools was primarily acquired through an informal usability study with a geology professor and four students in four one-on-one sessions. The professor described the environment to the student as if in an interactive lecture. Topics included the history of the Chicxulub Impact Crater and its impact on the terrain, such as patterns of sinkholes created by seismic waves. The professor would ask the student questions along the way related to the material, and both would interact by annotating the environment together. For example, the professor would explain what a sinkhole is and how it looks in the terrain, then ask the student to mark one with the point tool, and then could correct or adjust it if needed.

Both users were given minimal instruction on interaction and on the purpose of the collaborative tools, as we hoped to see how quickly they would understand the tools without help. Assistance or instruction from a proctor was only given upon direct request. The professor had tested earlier versions of the system, but no students had any familiarity with it.

During the session, the proctor asked the student and professor to perform tasks to encourage them to use the provided tools. Tasks pertaining to collaborative tools included finding each other in the environment and waving at one another, identifying a feature the other user was looking at, and coordinating annotation efforts based on described features. Tasks pertaining to menu interaction involved navigating to certain features on the terrain, saving and loading sets of annotations, and switching between annotation tools. After completing the lecture (of about 15 minutes), the users were asked about their experience, specifically about the importance and ease of maintaining awareness of the other user, the ease of using the menu, and the extent to which they used the features.

When teacher and student avatars were initially spawned far apart from each other in the environment, the users encountered no problems finding and navigating towards each other. While two students asked about the purpose of the tether, no users questioned what the gaze trail was, and they appeared to understand its purpose almost immediately. When asked to annotate a feature that the teacher was looking at, each understood that they should place the annotation near the gaze trail.

Users rated importance and three ease items from 1 to 7, with 1 representing little importance or great difficulty, and 7 representing great importance or great ease. All responses are shown in Table 1. When asked how important it was to stay aware of each others' physical locations in the environment (Q1 in Table 1), results were mixed, with an average rating of 4.6. The professor noted that it was not important for the majority of lecturing, as he could just focus on the environment and on explaining the material. Student 2 stated that seeing the gaze trail was sometimes not enough information for them, and they liked to be able to find the professor's avatar to determine his viewing direction.

When asked how easy it was to stay aware of each others' locations and states (Q2), ratings were high, with an average of 6.8. The professor pointed out that the wand pointer carried by the avatar and mapped to the direction of that user's controller made it easy enough to tell the user's orientation. When asked how easy it was to know where or what in the environment another user was talking about (Q3), all users responded with a 7, with all stating it was never difficult due to the gaze trail being so prominent in the otherwise static environment.

When asked if they used the tethers to find each other, all users said they did not. Instead, the professor and student 4 stated that they found it easier to look at the other user's wand pointer and follow that to their avatar. Student 2 pointed out that he looked at the nametag, but did not consciously notice the tether, comparing it to a lanyard that you ignore only to read what is attached to it. When asked if they used the remote view indicator on the nametags, all users said they did not, with all stating it was easier to use the gaze trail and they provided the same information. One student pointed out that he liked that the feature allowed him to look at the professor's avatar and still see what part of the environment he was talking about, but he still did not do this during the lecture.

When asked how easy it was to find the tools users needed within the menu (Q4), ratings were high, with an average of 6.2. Users stated that once they got used to the layout and the symbolism used to represent different tools, they did not have to think much about how to use the menu. No user rearranged the widget placements.

When asked whether they preferred to use the dashboard or the controller quick-select menu for changing movement, all users reported that they preferred the dashboard. Two students noted that they liked the idea of the controller menu but did not use it enough to get used to it. Two students also did not understand how to activate an option once they selected it until explicitly told that they only needed to look away from it.

5 DISCUSSION

Although we interpret results cautiously because of the small sample size, our strongest conclusion from observations and user feedback is that the gaze trail is promising for aiding in communicating attention. The professor appreciated its inclusion as it helped him know when students were paying attention to the feature he was describing. Students appreciated the feature for letting them know what feature the professor was describing when it was not immediately clear based on description.

The avatar, and its tether and remote view image to improve awareness of location and view, were described as less important by users than we expected. While in a standard classroom it may be considered normal to want to watch the teacher as they present material, in our system the students spent almost the entire time looking at the material being presented (the terrain below them). We expect this may be a consequence of the material being presented, the users' avatars being farther away from one another than is typical in a classroom, and possibly the avatar showing limited expression compared to humans.

The tethers appear to have been mostly unnoticed. However, based on two students' comments, we may consider that the tether was subconsciously guiding their gaze to the other user. Because ability to find the other user was not tested with and without the tether, it requires further investigation to see if the tether is a good tool that avoids active cognitive effort, or if it is just unnecessary.

Responses to the dashboard menu appeared to be mostly positive. Users found it intuitive and did not appear to struggle with finding the menu in the way we had seen for a static world-based menu. The fact that users never rearranged widgets suggests that this feature was either not emphasized enough or that users did not find it important for the study's short duration. The controller-based movement selection menu was not as well received. We consider that because the same tools could be found in the dashboard in a manner consistent with other features, and the dashboard had a smaller learning curve, users just opted for the most obvious option during the short experience. The primary concern appeared to be the method for activating a movement type. Users did not understand that the movement action was engaged only when not looking at the controller, motivating either a different selection method or an alternative method of scrolling through options. Because two students mentioned they liked the idea but could not learn it in time, we suggest the wand-based movement selector warrants further investigation.

Based on these results and feedback, we consider the ability for users, especially teachers, to understand the attentive state of the other user to be important. We can define this state to include the point in the environment at which the user is directing their attention, how much attention they are paying to that point, and how much cognitive effort is being put forth to understand the attended material. Using the gaze trail, teachers can determine if students are looking at the correct area, but gain little insight into their actual cognition. For example, a student may be watching the teacher's drawings along the terrain, but not be mentally engaged with the material, or they could be stressed by a lack of understanding. Based on prior research works, we believe this information can be garnered by using other eye tracking metrics and physiological signals from the user, and presented to teachers to help them better understand their students.

6 FUTURE WORK

6.1 Extending Indicators of Attention

It has long been understood that physiological signals given off by the body can help reveal a person's experiential state [6, 18, 29]. Notable examples relevant to understanding attentive states include using electrodermal activity to determine emotional engagement [8, 30], blinking rate and fixation time to determine cognitive load and area of attention [13, 22], cardiovascular activity to determine stress [4, 20, 21], and many others. We intend to capture metrics like these, analyze and visualize them for a teacher, and present them to the teacher in a way that will help them understand when a student is not paying attention or struggling with the material.

Multiple works have shown the possibility to combine multiple physiological signals to get a more complete picture of the user's state than is possible with any one signal [6]. While this has historically been done mostly offline after the full dataset can be analyzed [16], modern advances in hardware are making it more possible to perform online, with the ability to react to the information in real time [11, 29]. Analysis is mostly done using machine learning algorithms created from an established or created dataset (e.g. DEAP [15]) that labels physiological values to emotive states. Alternatively, designers can use domain knowledge of what different levels of signals often mean to determine a state.

We intend to create visualizations based on domain knowledge of these signals that will be interpreted by a combination of the system and user to determine an attentive state, then use this to create a dataset that can automate the process for future applications. Initial visualizations include things like a pulsing heart that matches a user's heart beat, with added glow or sweat when the user's heart rate or heart rate variability indicates a potential negative state (inattentive or stressed). Later visualizations will combine all of this information into a single index that can be understood more quickly. The interpreting user (the teacher) can then use this information to determine if the student may need attention.

6.2 Extending for Large Classrooms

When there are many students in the environment, many indicators will be created, likely causing a problem with clutter in the teacher's view. Given that the minimal indicators in the system at present could already produce a distracting amount of clutter, adding more to the environment may require a teacher to dedicate too much cognitive effort to interpret indicators.

To address this, we plan to aggregate information in a simplified manner, and show greater detail when students are detected to be in negative states or are requesting attention. For example, gaze trails can be combined and de-emphasized for a group of users looking at a similar area to reduce the number of moving objects on screen. Physiological data can be hidden until the system detects a high level of stress or inattention, then bring it to the teacher's attention to be addressed personally. Other indicators, like nametags and tethers, can be de-emphasized for students exhibiting normal or correct behavior, to further reduce cognitive load for the teacher.

6.3 Privacy and Security

When sharing personal data such as biometric data in networked VR, questions of privacy are important [17]. Our intent is not to record or force student attention, but rather to replace some of the awareness of others that is lost when moving from face-to-face meetings to VR and to help people work together voluntarily. Thus, we want to incorporate tools to let users control what is shared and to encourage responsible use of such technologies. Our algorithms for detecting user state will be built to be modular, using only the signals that the user deems comfortable sharing to give the best estimate possible with a given configuration. Users would then be able to toggle which signals should be sent using the menu, opt out entirely, or simply not wear certain sensors that are not included in the VR display. Users should be given a clear understanding of what information others will see and how it will be used.

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REFERENCES

[1] C. Ball and K. Johnsen. 2016. An accessible platform for everyday educational virtual reality. In *2016 IEEE 2nd Workshop on Everyday Virtual Reality (WEVR)*. 26–31.

[2] Marley Belair. 2012. The investigation of virtual school communications. *TechTrends* 56, 4 (2012), 26–33.

[3] Christoph W Borst, Gary L Kinsland, Vijay B Baiyya, Adam M Guichard, Arun P Indugula, Alp V Asutay, and Christopher M Best. 2006. System for interpretation of 3-D data in virtual-reality displays and refined interpretations of geophysical and topographic data from the Chicxulub Impact Crater. *Gulf Coast Association of Geological Societies Transactions* 56 (2006), 87–100.

[4] F. Bousefsaf, C. Maaoui, and A. Pruski. 2013. Remote assessment of the heart rate variability to detect mental stress. In *2013 7th International Conference on Pervasive Computing Technologies for Healthcare and Workshops*. 348–351.

[5] Susan E Brennan, Xin Chen, Christopher A Dickinson, Mark B Neider, and Gregory J Zelinsky. 2008. Coordinating cognition: the costs and benefits of shared gaze during collaborative search. *Cognition* 106, 3 (2008), 1465–1477.

[6] Benjamin Cowley, Marco Filetti, Kristian Lukander, Jari Torniainen, Andreas Henelius, Lauri Ahonen, Oswald Barral, Ilkka Kosunen, Teppo Valtonen, Minna Huotilainen, Niklas Ravaja, and Giulio Jacucci. 2016. The Psychophysiology Primer: A Guide to Methods and a Broad Review with a Focus on Human-Computer Interaction. *Found. Trends Hum.-Comput. Interact.* 9, 3–4 (Nov. 2016), 151–308. https://doi.org/10.1561/1100000065

[7] Raimund Dachselt and Anett Hübner. 2007. Three-dimensional menus: A survey and taxonomy. *Computers & Graphics* 31, 1 (2007), 53 – 65. https://doi.org/10.1016/j.cag.2006.09.006

[8] Elena Di Lascio, Shkurta Gashi, and Silvia Santini. 2018. Unobtrusive Assessment of Students' Emotional Engagement during Lectures Using Electrodermal Activity Sensors. *Proc. ACM Interact. Mob. Wearable Ubiquitous Technol.* 2, 3, Article 103 (Sept. 2018), 21 pages. https://doi.org/10.1145/3264913

[9] Kody R. Dillman, Terrance Tin Hoi Mok, Anthony Tang, Lora Oehlberg, and Alex Mitchell. 2018. A Visual Interaction Cue Framework from Video Game Environments for Augmented Reality. In *Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems* (Montreal QC, Canada) *(CHI '18)*. Association for Computing Machinery, New York, NY, USA, 1–12. https://doi.org/10.1145/3173574.3173714

[10] Sam Ekong, Christoph W. Borst, Jason Woodworth, and Terrence L. Chambers. 2016. Teacher-Student VR Telepresence with Networked Depth Camera Mesh and Heterogeneous Displays. In *Advances in Visual Computing*. Springer International Publishing, 246–258.

[11] S. H. Fairclough. 2009. Fundamentals of physiological computing. *Interacting with Computers* 21, 1-2 (2009), 133–145.

[12] Nico Feld and Benjamin Weyers. 2019. Overview of Collaborative Virtual Environments using Augmented Reality. In *Mensch und Computer 2019 - Workshopband*. Gesellschaft für Informatik e.V., Bonn. https://doi.org/10.18420/muc2019-ws-617

[13] A. Fowler, K. Nesbitt, and A. Canossa. 2019. Identifying Cognitive Load in a Computer Game: An exploratory study of young children. In *2019 IEEE Conference on Games (CoG)*. 1–6.

[14] Pascal Knierim, Thomas Kosch, Matthias Hoppe, and Albrecht Schmidt. 2018. Challenges and Opportunities of Mixed Reality Systems in Education. In *Mensch und Computer 2018 - Workshopband*, Raimund Dachselt and Gerhard Weber (Eds.). Gesellschaft für Informatik e.V., Bonn. https://doi.org/10.18420/muc2018-ws07-0471

[15] S. Koelstra, C. Muhl, M. Soleymani, J. Lee, A. Yazdani, T. Ebrahimi, T. Pun, A. Nijholt, and I. Patras. 2012. DEAP: A Database for Emotion Analysis ;Using Physiological Signals. *IEEE Transactions on Affective Computing* 3, 1 (2012), 18–31.

[16] Christine L. Lisetti and Fatma Nasoz. 2004. Using Noninvasive Wearable Computers to Recognize Human Emotions from Physiological Signals. *Journal on Advances in Signal Processing* 2004 (2004). Issue 11.

[17] Isma Masood, Yongli Wang, Ali Daud, Naif Radi Aljohani, and Hassan Dawood. 2018. Privacy management of patient physiological parameters. *Telematics and Informatics* 35, 4 (2018), 677 – 701. https://doi.org/10.1016/j.tele.2017.12.020

[18] Iris Mauss, Robert Levenson, Loren McCarter, Frank Wilhelm, and James Gross. 2005. The Tie That Binds? Coherence Among Emotion Experience, Behavior, and Physiology. *Emotion* 5, 2 (2005), 175–190.

[19] Keenan R May, Briana Sobel, Jeff Wilson, and Bruce N Walker. 2019. Auditory displays to facilitate object targeting in 3D space. In *Proceedings of the 25th International Conference on Auditory Display*. Georgia Institute of Technology, 155–162.

[20] D. McDuff, S. Gontarek, and R. Picard. 2014. Remote measurement of cognitive stress via heart rate variability. In *2014 36th Annual International Conference of the IEEE Engineering in Medicine and Biology Society*. 2957–2960.

[21] Daniel J. McDuff, Javier Hernandez, Sarah Gontarek, and Rosalind W. Picard. 2016. COGCAM: Contact-Free Measurement of Cognitive Stress During Computer Tasks with a Digital Camera. In *Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems* (San Jose, California, USA) *(CHI '16)*. Association for Computing Machinery, New York, NY, USA, 4000–4004. https://doi.org/10.1145/2858036.2858247

[22] Nargess Nourbakhsh, Yang Wang, and Fang Chen. 2013. GSR and Blink Features for Cognitive Load Classification. In *Human-Computer Interaction – INTERACT 2013*, Paula Kotzé, Gary Marsden, Gitte Lindgaard, Janet Wesson, and Marco Winckler (Eds.). Springer Berlin Heidelberg, Berlin, Heidelberg, 159–166.

[23] Madeline Ortiz-Rodríguez, Ricky W Telg, Tracy Irani, T Grady Roberts, and Emily Rhoades. 2005. College Students' Perceptions of Quality in Distance Education: The Importance of Communication. *Quarterly Review of Distance Education* 6, 2 (2005), 97.

[24] Matthew Plumlee and Colin Ware. 2003. An Evaluation of Methods for Linking 3D Views. In *Proceedings of the 2003 Symposium on Interactive 3D Graphics* (Monterey, California) *(I3D '03)*. Association for Computing Machinery, New York, NY, USA, 193–201. https://doi.org/10.1145/641480.641517

[25] Pernilla Qvarfordt, David Beymer, and Shumin Zhai. 2005. RealTourist – A Study of Augmenting Human-Human and Human-Computer Dialogue with Eye-Gaze Overlay. In *Human-Computer Interaction - INTERACT 2005*, Maria Francesca Costabile and Fabio Paternò (Eds.). Springer Berlin Heidelberg, Berlin, Heidelberg, 767–780.

[26] Y. Rahman, S. M. Asish, N. P. Fisher, E. C. Bruce, A. K. Kulshreshth, and C. W. Borst. 2020. Exploring Eye Gaze Visualization Techniques for Identifying Distracted Students in Educational VR. In *2020 IEEE Conference on Virtual Reality and 3D User Interfaces (VR)*. 868–877.

[27] P. Renner and T. Pfeiffer. 2017. Attention guiding techniques using peripheral vision and eye tracking for feedback in augmented-reality-based assistance systems. In *2017 IEEE Symposium on 3D User Interfaces (3DUI)*. 186–194.

[28] Sylvia Rothe, Daniel Buschek, and Heinrich Hußmann. 2019. Guidance in Cinematic Virtual Reality-Taxonomy, Research Status and Challenges. *Multimodal Technologies and Interaction* 3, 1 (2019). https://www.mdpi.com/2414-4088/3/1/19

[29] Lin Shu, Jinyan Xie, Mingyue Yang, Ziyi Li, Zhenqi Li, Dan Liao, Xiangmin Xu, and Xinyi Yang. 2018. A Review of Emotion Recognition Using Physiological Signals. *Sensors* 18, 7 (Jun 2018), 2074. https://doi.org/10.3390/s18072074

[30] Idalis Villanueva, Brett D. Campbell, Adam C. Raikes, Suzanne H. Jones, and LeAnn G. Putney. 2018. A Multimodal Exploration of Engineering Students' Emotions and Electrodermal Activity in Design Activities. *Journal of Engineering Education* 107, 3 (2018), 414–441. https://doi.org/10.1002/jee.20225 arXiv:https://onlinelibrary.wiley.com/doi/pdf/10.1002/jee.20225

[31] J. O. Wallgrün, A. Masrur, J. Zhao, A. Taylor, E. Knapp, J. Chang, and A. Klippel. 2019. Low-Cost VR Applications to Experience Real Word Places Anytime, Anywhere, and with Anyone. In *2019 IEEE 5th Workshop on Everyday Virtual Reality (WEVR)*. 1–6.

[32] C. Ware, M. Plumlee, R. Arsenault, L. A. Mayer, and S. Smith. 2001. GeoZui3D: data fusion for interpreting oceanographic data. In *Proceedings of the 2001 MTS/IEEE Oceans Conference*, Vol. 3. 1960–1964 vol. 3.

[33] A. Yoshimura, A. Khokhar, and C. W. Borst. 2019. Eye-gaze-triggered Visual Cues to Restore Attention in Educational VR. In *2019 IEEE Conference on Virtual Reality and 3D User Interfaces (VR)*. 1255–1256.

[34] Yanxia Zhang, Ken Pfeuffer, Ming Ki Chong, Jason Alexander, Andreas Bulling, and Hans Gellersen. 2017. Look together: using gaze for assisting co-located collaborative search. *Personal and Ubiquitous Computing* 21, 1 (2017), 173–186.