An EEG-Based Study Investigating Cognitive and Behavioral Reactions to Indian Knowledge System Narratives in Virtual Reality

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Abstract: Virtual reality (VR) storytelling has been demonstrated to impact emotional and cognitive capacities. Still, less is known about the precise impacts of VR on moral learning and engagement, especially when it comes to Indian Knowledge System (IKS) stories. In order to close this gap, this study examines the moral learning and engagement potential of VR-based storytelling in comparison to traditional reading. Three groups of 75 individuals each were assigned to VR, reading, and control. The VR and reading groups outperformed the control group in terms of moral learning and retention, according to behavioral data, which did not reveal any significant differences between them. However, according to the EEG data, the VR group was more engaged than the reading group, as evidenced by a lower alpha band power. Participants using VR showed higher engagement, as evidenced by 88% of responses indicating agreement or strong agreement on a five-point Likert scale. These results imply that while reading and VR are equally helpful for moral learning, VR is more engaging due to its immersive features.

1 INTRODUCTION

Storytelling makes it easier to understand moral lessons and remember information by turning complicated subjects into interesting and memorable stories (Tappan and Brown, 1989). Narrative styles help us understand and clarify information, especially in news reporting and brand storytelling (Tappan and Brown, 1989), (Machill et al., 2007). Instance-based Learning Theory (IBLT) indicates that using vivid examples in stories can improve recall and decision-making (Gupta et al., 2021).

Vedas based Indian Philosophy, emphasizes how important stories are in teaching morals (Whittemore, 1966). The Indian Knowledge System (IKS) serves up some serious wisdom through tales like the Panchatantra and Ramayana, teaches moral lessons that stay with you (Whittemore, 1966), (Mahadevan and Bhat, 2022). These stories teach important lessons and help build our understanding of right and wrong. These tales typically make their rounds in text form, and diving into them is key to grasping the moral values they offer.

However, the Immersive technologies like VR offer new opportunities for moral education. VR enhances moral education by improving engagement and retention through lifelike experiences (Sen, 2007). VR allows users to engage with IKS tales in meaningful, personalized ways (Akbar et al., 2013). Previous research has explored VR and storytelling's educational roles (Rueda and Lara, 2020). While VR enhances classroom engagement, its role in moral learning with IKS remains underexplored (Akbar et al., 2013), (Rueda and Lara, 2020).

These stories are usually shared through text, and you need to read them to learn the moral lessons they offer (Pan and Hamilton, 2018). Figuring out how VR impacts our thinking and feelings is still tough. Traditional evaluations usually don't capture how engaged someone is cognitively when they're experiencing immersive storytelling. EEG helps to fill this gap by providing an objective measurement of cognitive engagement.

EEG offers a clear view into brain activity and may

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provide light on the cognitive processes linked to various learning modalities. Neurological oscillations in different frequency bands (beta, gamma, and alpha) are measured by EEG, which reveals patterns of cognitive engagement, attention, and memory retention (Singh et al., 2021), (Chauhan et al., 2024). More specifically, higher beta and gamma activity suggests more cognitive load and attention, whereas lower alpha band power has been associated with greater involvement (Engel and Fries, 2010), (Klimesch, 1999). Therefore, EEG-based research offers an unbiased way to measure the cognitive impacts of immersive storytelling, enabling a deeper comprehension of how VR affects moral learning.

This work intends to close the knowledge gap about the neurological processes behind VR-based storytelling, especially in the context of IKS, since there has been a dearth of research in this area. Comparing VR to conventional reading-based narrative, we may assess how VR affects moral retention and cognitive engagement using EEG data. Determining the educational effectiveness of VR depends on comprehending these brain patterns because they give quantifiable, tangible proof of cognitive engagement that goes beyond what can be obtained from conventional behavioral tests.

The following research issues are intended to be addressed by this study: 1) How do conventional reading-based storytelling techniques and VR compare in terms of event recollection from IKS stories? 2) How do these techniques affect neuronal engagement during learning as determined by EEG? We hypothesize that, in comparison to traditional reading-based storytelling, VR storytelling will elicit greater cognitive engagement, improve retention of story events (H1), and increase neural activity in the gamma and beta frequency bands (H2). This is based on the Instance-based Learning Theory (IBLT) (Gupta et al., 2021) and previous research on VR's cognitive benefits (Whittemore, 1966).

The EEG-based study contributes to the growing understanding of VR's educational potential, especially in moral instruction through IKS stories. We aim to gather quantitative data on the neurological aspects of immersive moral teaching by using VR storytelling and modern EEG techniques. This will provide teachers, tech experts, and curriculum creators with new insights.

2 BACKGROUND

This will provide teachers, tech experts, and curriculum creators with new insights.Storytelling is a popular method for improving moral lessons and helping with memory retention. Telling stories makes complicated ideas easier to understand and helps us remember things better through interesting narratives. Narratives help us understand and remember information in different forms of media (Tappan and Brown, 1989), (Machill et al., 2007). Instance-based Learning Theory (IBLT) highlights how storytelling can improve memory when making decisions (Gupta et al., 2021). IBLT indicates that narratives can shape choices by triggering clear memories (Gupta et al., 2021).

IKS is known for emphasizing the importance of values in its teaching. IKS have their foundations in the Vedas, which share philosophical and ethical lessons through narratives such as the Panchatantra and Ramayana (Whittemore, 1966), (Mahadevan and Bhat, 2022). The stories put impact on us by telling how things are right and wrong. Similar ways Panchatantra works by using fables to share important moral and social lessons. Moral lessons are not limited to just educational purposes; they also provide entertainment, making them ideal for conveying messages that really ring.

In education, storytelling has usually relied on text. Text-based storytelling is really important for teaching morals. Studies indicate that reading improves retention, whereas digital storytelling engages learners in unique ways (Sen, 2007). The immersive nature of VR really boosts engagement and understanding, which is why it's become such a popular narrative medium. The interactive settings in VR really help with recall and make learning feel more personal (Akbar et al., 2013), (Rueda and Lara, 2020).

VR's immersive features foster deeper engagement, aiding learning (Akbar et al., 2013). VR also enhances the learner's connection with the material, and making things easier to understand. VR offers a more engaging alternative to traditional reading methods (Rueda and Lara, 2020). (Rueda and Lara, 2020) argued that VR could foster ethical empathy by allowing learners to experience narratives in a more emotionally resonant way, particularly when teaching sensitive moral topics (Sen, 2007). However, there still lacks research specifically examining VR's potential to enhance moral education through IKS narratives.

While a great deal of research has been done on education, not much has been done to examine the potential effects of VR storytelling on moral retention and cognitive engagement—especially in comparison to more conventional reading-based approaches. This study uses electroencephalography (EEG) to quantify cognitive involvement during storytelling objectively in order to close this gap. Neural oscillations associated with varying degrees of cognitive load, attention, and memory processes are captured by EEG, which is a useful technique for monitoring brain activity in real time (Engel and Fries, 2010). While increases in beta and gamma band activity are linked to greater cognitive load and attention during immersive experiences, decreased alpha band power has been linked to higher levels of cognitive engagement (Klimesch, 1999). Through the use of EEG, researchers can learn more about the cognitive processes involved in engagement with VR or reading based storytelling.

The purpose of this study is to investigate how well VR storytelling compares to traditional reading-based storytelling when it comes to imparting moral lessons using IKS storylines. It aims to measure how various storytelling media impact engagement, memory retention, and the cognitive processes involved in learning through behavioral tests and EEG data. We predict that participants exposed to VR storytelling will exhibit higher levels of cognitive engagement and moral retention than those participating in traditional reading-based learning because of the immersive character of VR. The results of this study will add to the expanding corpus of research on VR's educational uses, especially in moral education. They will also provide useful advice on how to use technology to teach culturally relevant stories.

3 METHODS

3.1 Experimental Design

G*Power (Faul, 2007) was used to calculate the necessary sample size. The results showed that 25 individuals were needed for each group, for a total of 75 participants across the three treatments. The target effect size for this sample size was 0.36, with a 0.05 alpha threshold and 0.80 statistical power. Participants were selected randomly. Figure 1 illustrates the experimental layout. There were 25 individuals in each of the three groups—reading, VR, and control—who were assigned at random.

The reading group read the tale on paper, while the VR group used VR headsets. Whereas, the control group was only given moral as a keyword. The study comprised pre-, during-, and post-study stages. Pre-study data included consent, demographics, and educational background to assess eligibility. During the intervention the reading and VR group were engaged with the respective intervention.

EEG recordings measured cognitive involvement during the story engagement. Pre- and during-study EEG data were collected for the VR and reading groups. EEG analysis focused on alpha, beta, and gamma oscillations to assess cognitive load and engagement. Decrease in alpha power and increase in beta/gamma activity indicated cognitive engagement (Engel and Fries, 2010). These measures objectively compared cognitive involvement across groups.

Post-study questionnaires assessed moral lesson retention across groups. Participants summarized the story's main points in their own words. Semantic similarity of responses was evaluated using a sentence transformer (Reimers and Gurevych, 2020). Cosine similarity quantified retention across narrative modes (Reimers and Gurevych, 2020).

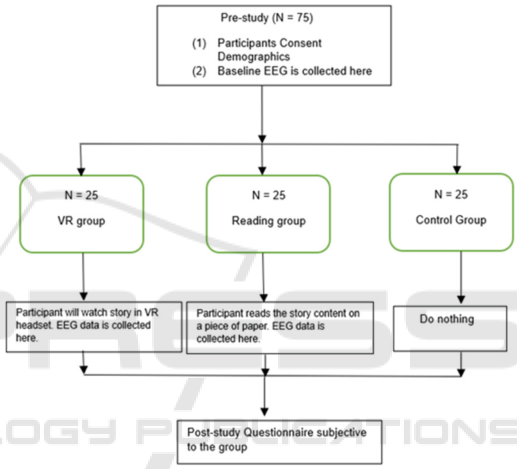

Figure 1: The experimental design of the study outlines the three between-subject conditions and the corresponding interventions provided to each group.

3.2 Participants

The research was authorized by the Institutional Ethical Committee and carried out strictly in accordance with the Helsinki Declaration (World Medical Association, 2024). In this study, 75 healthy individuals were randomly and evenly assigned to groups using a double-blind, placebo-controlled protocol. The participants were chosen from a collegiate setting and ranged in age from 18 to 30 years old (M = 21, SD = 1.71). The sample consisted of 65% male and 35% female individuals. Ninety-nine percent were pursuing undergraduate degrees, and one percent had a PhD. As payment for their participation, individuals who completed the study received academic prizes (2 bonus marks in a computer science course).

3.3 Materials

The story "The Woodcutter and Her Axe" was selected for this study based on a careful examination of several Panchatantra stories, with a focus on the moral virtue of "honesty." The main characters in this tale are the woodcutter and an angel. The tale was presented to the VR and reading groups in the same manner to maintain uniformity in storytelling and avoid discrepancies between the two treatments. The following sections provide a detailed description of the particular stimuli that were used for each group.

3.4 VR Group

Participants in the VR intervention saw the tale using a 3D VR 2.0 headset and a Bnext VR headset (Marquez, 2023). A picture of the VR environment may be seen in Figure 2. CoSpaces software (CoSpaces Edu, 2019) was used to build the story's scenes, and it also helped elicit emotions consistent with the actions of the characters. In the VR group, participants saw the tale in VR and engaged in discourse. With the help of CoSpaces software, which offers a large selection of 3D models, textures, and other materials to improve the narrative process, an immersive 3D experience of the scenes was created. At this link, you may see the narrative that was made in the VR environment.

Figure 2: Scene shown in VR group depicting the dialogue exchange between the woodcutter and the angel.

3.5 Reading Group

The participants in the reading group read the story on paper. To avoid any differences, the scenes shown in CoSpaces were matched with the written story. This made sure that both the VR group and the text group experienced the same story.

3.6 Control Group

The participants in the control group have received only the keyword as a moral "Honesty is the best policy".

3.7 EEG Data Processing

First, a 50 Hz notch filter was applied to Muse S headband EEG data at 256 Hz. Brain waveband discrepancies were accurate with visual feedback. We normalized eye blinks and jaw clenches with a Butterworth filter. Multiple brainwave bands and channels were evaluated by converting power to linear scale (Linear Power = 10^ (Power in Bels)), calculating average power, and calculating ratios such as Frontal Alpha to Temporal Theta and Alpha/Beta across all channels. Calculations were consistent across time and participants.

3.8 Statistical Analysis

Data analysis utilized IBM SPSS 21.0 Statistics (IBM Corp., 2017), incorporating descriptive statistics to evaluate sample size and variable interpretation. An ANOVA compared the three groups (reading, VR, and control) across baseline and intervention times, requiring homogeneity, sphericity (confirmed by Mauchly's test), and normalcy. Levene's test verified homogenous variances. With a power of 0.8 and an alpha level of 0.05, significant effects led to post-hoc analyses like Tukey's HSD for detailed group comparisons and effect sizes (partial eta squared) to assess the results' practical significance.

4 RESULTS

4.1 Behavioral Measure

4.1.1 Moral Retention

We analysed participants' responses to the prompt, "In your own words, describe the main events of the story?" across the VR, reading, and control groups. Figure 4 presents the cosine similarity between the VR and reading group (V-R), VR and control group (V-C), and reading and control group (R-C). There was a significant difference in the cosine similarity index between the groups [$F(2, 1872) = 4867.5$, $p < .01$, $\eta^2 = .84$]. Post-hoc Tukey tests showed significant differences between the V-R and V-C groups and between the V-R and R-C groups, with V-R showing higher similarity (V-R: $\mu = 0.67 >$ V-C: $\mu = 0.14$, $p < .01$; V-R: $\mu = 0.67 >$ R-C: $\mu = 0.16$, $p < .01$). However, there was no significant difference between the V-C and R-C groups (V-C: $\mu = 0.14 \sim$ R-

C: μ = 0.16, $p = .06$). As expected, the VR and reading groups exhibited greater retention similarity compared to the control group.

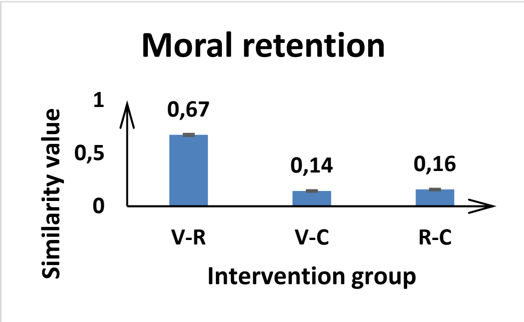

Figure 3: For retention, the similarity value was obtained through a sentence transformer. The error bar shows the 95% CI around point estimates.

4.1.2 Engagement Score

Participants' responses to the question, "I felt engaged with the story. (Here, 1 is Strongly Disagree, 2 is Disagree, 3 is Neutral, 4 is Agree and 5 Strongly Agree.) was analysed across the VR group. Figure 5 presents the responses obtained against five-point Likert scale values. Here, the mean engagement score obtained was 4, resembling participants agreement toward engagement with the VR setup.

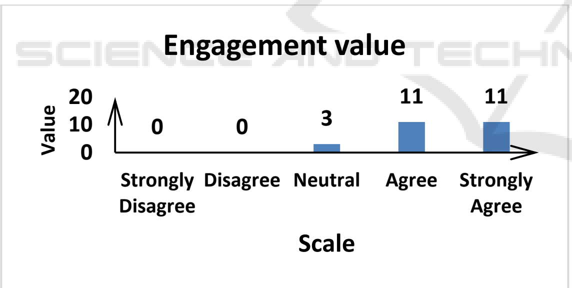

Figure 4: For engagement, the value was obtained over five-point Likert scale which ranges from strongly disagree to strongly agree.

5 NEURAL MEASURES

5.1.1 Gamma/Beta (TP9, TP10 Channels)

Figure 5 illustrates the Gamma/Beta ratio across the VR, reading, and control groups. A significant main effect of the intervention on the Gamma/Beta ratio was observed [$F(2, 72) = 3.32, p < .05, \eta^2 = .08$]. Post-hoc analysis revealed a significant difference between the VR and reading groups, with higher values in the VR group (VR: μ = 1.41 > Reading: μ = 0.66, $p < .05$). No significant differences were found between the reading and control groups (Reading: μ = 0.66 ~ Control: μ = 0.79, $p = .85$), or between the VR and control groups (VR: μ = 1.41 ~ Control: μ = 0.79, $p = .15$). The effect of time (baseline vs. during intervention) was not significant [$F(2, 72) = 1.71, p = .20, \eta^2 = .03$], and no significant interaction between group and time was found [$F(2, 74) = 2.70, p = .08, \eta^2 = .07$]. While baseline measures were comparable across groups, the VR group demonstrated an increased Gamma/Beta ratio during the intervention (VR: 1.41; Reading: 0.66; Control: 0.79).

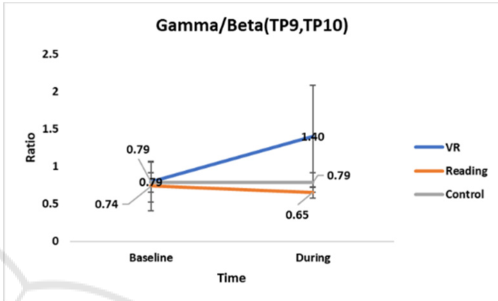

Figure 5: Gamma/Beta ratio of TP9 and TP10 channels across the groups (VR, reading and control).

5.1.2 Alpha/Theta (TP9, TP10)

As shown in Figure 6, the Alpha/Theta ratio differed significantly between groups [$F(2, 72) = 5.79, p < .01, \eta^2 = .84$]. Post-hoc testing revealed that the reading group had a significantly higher Alpha/Theta ratio than the control group (Reading: μ = 2.15 > Control: μ = 1.13, $p < .01$), though there was no significant difference between the reading and VR groups (Reading: μ = 2.15 > VR: μ = 1.47, $p = .07$) or the VR and control groups (VR: μ = 1.47 ~ Control: μ = 1.13, $p = .52$). The main effect of time was significant [$F(2, 72) = 11.03, p < .01, \eta^2 = .14$], as was the interaction between group and time [$F(2, 74) = 4.55, p < .05, \eta^2$

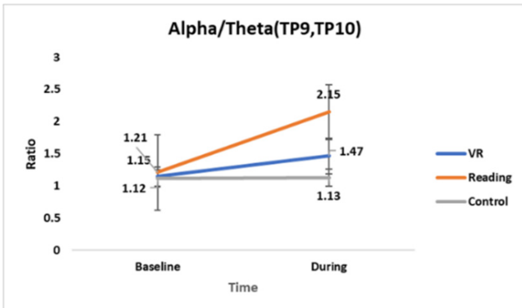

Figure 6: Alpha/Theta ratio of TP9 and TP10 channels across the groups (VR, reading and control).

= .12]. While baseline measures were comparable (VR: 1.15; Reading: 1.21; Control: 1.12), post-intervention results showed an increase in the Alpha/Theta ratio in the reading group (2.15) compared to VR (1.47) and control (1.13).

5.1.3 Alpha/Theta (AF7, AF8)

Figure 7 highlights the significant main effect of intervention on the Alpha/Theta ratio for AF7 and AF8 channels [$F(2, 72) = 11.74$, $p < .01$, $\eta^2 = .25$]. Post-hoc analysis showed significant differences between both VR and control (VR: $\mu = 1.49 >$ Control: $\mu = 0.79$, $p < .01$) and reading and control groups (Reading: $\mu = 1.73 >$ Control: $\mu = 0.79$, $p < .01$). However, no significant difference was observed between the VR and reading groups (Reading: $\mu = 1.73 \sim$ VR: $\mu = 1.49$, $p = .40$). Significant effects of time [$F(2, 72) = 128.47$, $p < .01$, $\eta^2 = .65$] and time-by-group interaction [$F(2, 74) = 32.27$, $p < .01$, $\eta^2 = .48$] were also found. Increases in the Alpha/Theta ratio were observed in both the reading (1.74) and VR (1.50) groups compared to the control group (0.79).

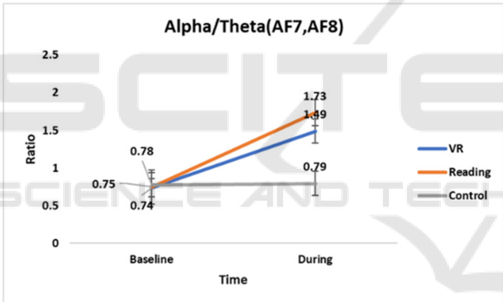

Figure 7: Alpha/Theta ratio of AF7 and AF8 channels across the groups (VR, reading and control).

5.1.4 Alpha/Beta (TP9, TP10)

Figure 8 shows that the main effect of intervention on the Alpha/Beta ratio was not significant [$F(2, 72) = 1.24$, p = .30, $\eta^2 = .03$], nor were the main effect of time [$F(2, 72) = .77$, p = .38, $\eta^2 = .01$] or the interaction between group and time [F(2, 74) = 1.01, p = .36, $\eta^2 = .02$].

5.1.5 Alpha/Beta (AF7, AF8)

The main effect of intervention on the Alpha/Beta ratio for AF7 and AF8 channels was significant [see Figure 9; [$F(2, 72) = 4.38$, $p < .05$, $\eta^2 = .11$]. Post-hoc tests indicated a significant difference between the reading and control groups (Reading: $\mu = 1.38 >$ Control: $\mu = 0.86$, $p < .05$), though no significant

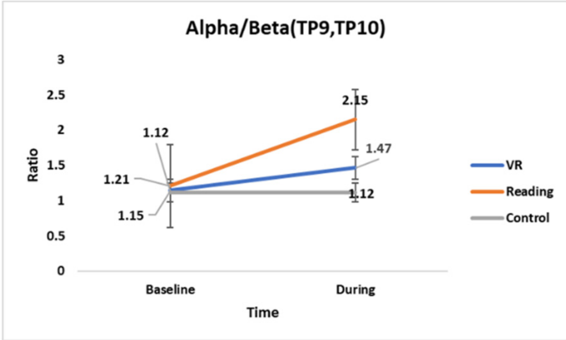

Figure 8: Alpha/Beta ratio of TP9 and TP10 channels across the groups (VR, reading and control).

differences were found between the VR and reading groups (VR: $\mu = 1.22 \sim$ Reading: $\mu = 1.38$, $p = .49$) or the VR and control groups (VR: $\mu = 1.22 \sim$ Control: $\mu = 0.86$, $p = .19$). There was a significant main effect of time [$F(2, 72) = 12.18$, $p = .01$, $\eta^2 = .15$] and a significant time-by-group interaction [$F(2, 74) = 3.16$, $p < .05$, $\eta^2 = .08$].

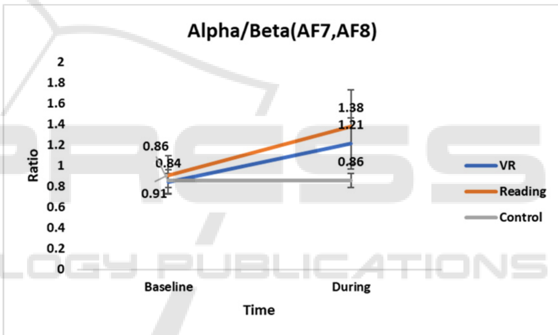

Figure 9: Alpha/Beta ratio of AF7 and AF8 channels across the groups (VR, reading and control).

5.1.6 Beta/Theta (TP9, TP10)

Figure 10 displays the Beta/Theta ratio across the VR, reading, and control groups. A significant main effect of the intervention was observed [$F(2, 72) = 1.10$, $p < .05$, $\eta^2 = .03$], as well as a significant main effect of time (baseline vs. during intervention) [$F(2, 72) = 49.19$, $p < .01$, $\eta^2 = .40$]. Additionally, the interaction between group and time was significant [$F(2, 74) = 14.88$, $p < .01$, $\eta^2 = .30$]. While no baseline differences were detected between the groups (VR: 0.84; Reading: 0.84; Control: 0.85), the VR group showed an increase in Beta/Theta ratio (1.45), and the reading group exhibited an even larger increase (1.89), compared to the control group (0.85).

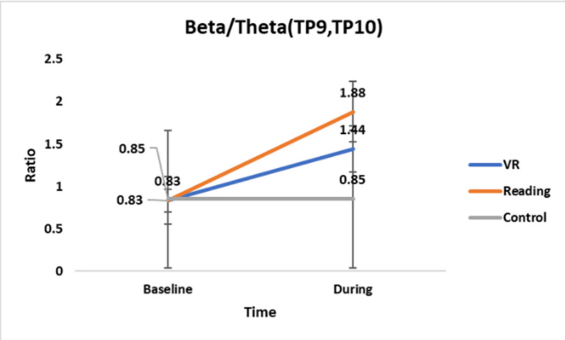

Figure 10: Beta/Theta ratio of TP9 and TP10 channels across the groups (VR, reading and control).

5.1.7 Beta/Theta (AF7, AF8)

Figure 11 illustrates the Beta/Theta ratio for the VR, reading, and control groups. The main effect of the intervention on the Beta/Theta ratio was significant [$F(2, 72) = 1.06$, $p < .05$, $\eta^2 = .03$], as was the main effect of time (baseline vs. during intervention) [$F(2, 72) = 14.50$, $p < .01$, $\eta^2 = .17$]. There was also a significant interaction between group and time [$F(2, 74) = 4.16$, $p < .05$, $\eta^2 = .11$]. No differences were observed at baseline between the groups (VR: 0.99; Reading: 1.05; Control: 1.01), but post-intervention increases were seen in both the VR (2.01) and reading groups (2.57) compared to the control group (0.79).

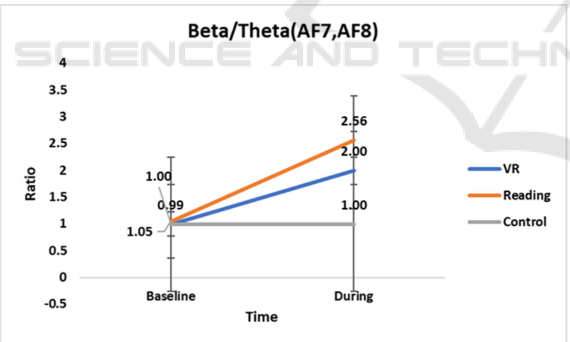

Figure 11: Beta/Theta ratio of AF7 and AF8 channels across the groups (VR, reading and control).

6 DISCUSSION

Findings confirm that VR storytelling enhances cognitive engagement due to its immersive quality. Both VR and reading improved moral recall compared to the control group. EEG results highlight VR's unique role in enhancing cognitive arousal through lower alpha power and higher gamma/beta ratios. This aligns with prior research on VR's immersive nature boosting mental participation (Pan and Hamilton, 2018).

It seems that VR storytelling probably requires more cognitive processing, which is suggested by the higher gamma/beta ratios. This suggests that immersive environments need a greater amount of cognitive effort (Tappan and Brown, 1989), (Rueda and Lara, 2020). Even though VR and reading had different levels of engagement, they were both equally effective in helping with moral retention. Even though VR boosts engagement, it doesn't necessarily lead to better learning results.

Education is a best area where we can use the technology like VR, however its important to see VR's capability in engagement than retention. VR advantage with engagement is quite worth, it doesn't stand apart with reading for moral retention. This matches what the literature says about VR's potential in teaching moral and ethical concepts (Rueda and Lara, 2020). This also raise a question whether technology always leads to improved learning. VR might improve motivation and emotional engagement, which are important for learning, but it doesn't guarantee retention.

EEG helps in measuring the cognitive engagement. EEG provides new perspectives on how different teaching methods impact cognitive load and engagement. EEG helps in investigating the minute details of cognitive engagement that behavioral data may skip. This helps to give a better understanding of how immersive technologies, like VR, influence learning processes (Sen, 2007), (Rueda and Lara, 2020), (Chauhan et al., 2024). VR storytelling alongside traditional reading method can increase engagement (Rueda and Lara, 2020). Incorporating VR storytelling with traditional teaching methods can significantly boost engagement. Using VR is way more effective when it's combined with traditional methods rather than just relying on it alone.

7 PRACTICE AND THEORY REPERCUSSIONS

The VR can be used effectively in teaching moral where students need to be engaged. VR is most effective when it's used alongside traditional methods, instead of just being a standalone tool.

VR mustn't be misinterpreted for using as a better learning tool, despite it can lead to increase cognitive load and engagement.

This highlights the importance of looking into the connections between engagement, motivation, and learning results. Both VR and reading help with moral teaching, but VR has some unique advantages in terms of engagement. VR's immersive nature should be enhanced in the future work while using traditional methods alongside.

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