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Effect of a Mindfulness intervention with virtual reality in adolescents on Attention and working memory

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Abstract

Introduction: Mindfulness has proven to be a very valuable practice to improve people's attentional and working memory capacities. These abilities evolve over time, but if they are properly trained, they can reach greater potential, especially if this training is done during childhood and adolescence. Adolescents do not always feel motivated to practice mindfulness, so the aim of this work consists in proposing a mindfulness intervention through the use of a virtual reality headset that allows access to mindfulness training in a way that is more attractive to them.

Method. An experimental design was used to evaluate the effect of a Mindfulness intervention with virtual reality (MIVR) using the app TRIPP, in a sample of 47 adolescents (G_1n= 25, G_2n= 22; mean age = 15.53; *SD* = .99; 57.44% female) trough The RehaCom Screening Test on Divided Attention (DA) and Working Memory (WM), before (T_1 = pretest), and 21 days after its implementation (T_2 = posttest).

Results: The results showed that there was a significant difference between the experimental and control groups between measurements (T_2 T_1), in terms of divided attention and working memory ($p < 0.001$), but not between woman and man, suggesting a significant improvement in 21 days of the MIVR.

Discussion. This research corroborates and contributes to a better understanding of the direct effects on Virtual Reality-Mindfulness interaction, also verifying that adherence to monitoring the process gives evidence of the motivation acquired by adolescents.

Keywords: Mindfulness, Intervention, Tripp, Oculus Rift S, Virtual Reality, RehaCom, Attention, Working Memory, Adolescence.

Introduction

Mindfulness implies full attention, a way of focusing on the present moment, as a psychological process it means focusing attention on what is being done or feeling (Vásquez-Dextre, 2016), this has been shown in research, where it is observed how mindfulness improves attention, memory, the emotional state and its regulation (Basso, et al., 2019). In children and adolescents, improvement in attention and other executive functions has been confirmed (Dunning, et al., 2019).

In this sense, it is known that adolescents need to feel motivated to learn (Limón & Carretero, 1995) and that these experiences are attractive or pleasant, especially linked to technologies (Garitaonandia, et al., 2005), so doing mindfulness, turns out to be more attractive, in addition to the fact that training children and adolescents in any aspect at an early age is better than waiting until they reach adulthood (Limón & Carretero, 1995).

According to the American Psychological Association, mindfulness meditation, also called mindfulness, is defined as the training of attention to achieve a mental state of calm concentration and positive emotions. In this, two parts are considered: attention and acceptance. The first seeks to tune into experiences to focus on what is happening in the present moment, achieving it through the direction of breathing, thoughts, physical sensations, and feelings. The second, acceptance, implies observing what is being experienced without judging, that is, instead of responding or reacting, those emotions are allowed to pass. (APA, 2019).

The benefit of mindfulness is both psychic and physical, it is used to deal with stress and other difficult emotions such as anger and the lack of control that derives from it. It helps the thoughts to have more objectivity, to recognize the states that alter or influence those thoughts. This means that instead of repressing or reacting to negative emotions, which are the two common states of emotional regulation, mindfulness helps to 'be with' the emotions and separate the rawness of those emotions, along with the feelings and thoughts that surround (Naik, et al., 2013).

Creswell (2017) described an evaluation article on mindfulness-based interventions for health, cognition, affectivity, and interpersonal relationships, as well as applications targeting settings and populations (work, school, military), the mechanisms neurobiological and psychological among other aspects. This research found that mindfulness interventions improve outcomes in multiple domains ranging from chronic pain to addictions, for example.

In a review article of randomized controlled trials regarding the effects of mindfulness-based interventions on cognition and mental health in children and adolescents, it was found that all trials found significant improvements in mindfulness versus controls in categories such as executive functioning, attention, depression, anxiety, stress, and negative behaviors (Dunning, et al., 2019).

Virtual reality (VR) is understood as a man-machine interface using computer-generated simulators, it is also a synthetic experience where physical reality is substituted to achieve an immersive interaction between the user and the world (Pérez, 2011).

Heras and Villarreal (2004) described that this technology dates back to 1960, but its use was until the end of the 20th century, maturing in components such as hardware, software, applications, and content. Its use has been directed mainly at education, art, entertainment, dissemination of science and technology, museums, products, storytelling, and even in the military industry. The expression virtual reality goes back to some discussions about the context of technologies among technologists such as J. Lanier, t. Nelson, M. Krueger, and J. Walker raised the practical problem of relating more humanely and naturally between a user and the interface (Castañares, 2011).

The first applications of VR in psychology were focused on exposure techniques used in phobias, but also in psychic and psychomotor rehabilitation, although there were also antecedents that were aimed at general psychological treatment and anxiety in students (Gutiérrez, 2002).

VR as a tool in general and specialized care services, as well as in psychotherapy, has been sustained as an effective strategy (Riva, 2005). Comparing them with traditional treatments, VR has advantages such as the protected environment for the patient and the re-experiencing of a truly felt situation. Evidence of effectiveness in anxiety, eating, and sexual disorders has also been recovered (Botella, et al., 2004). Even so, much research is lacking to support this effectiveness in mental health (Gregg & Tarrier, 2007). In an experiment to investigate the influences of VR on dissociation, mindfulness, and self-efficacy, the results showed that participants who were immersed in a VR system for 20 minutes increased dissociation and a significant increase in mindfulness after being immersed in simulation (Mondellini, et al., 2021). Also, in studies where VR was used for attentional and memory improvement in adults, it was shown to be more efficient than computerized (Climent, et al., 2021). Virtuality offers an innovative way to research, to live experiences, and to train (Argüero-Fonseca, et al., 2021; Modrego-Alarcón, et al., 2021), adolescents are more attracted, manages to link these two practices, mindfulness and virtual reality, to improve attentional aspects and working memory.

Adolescence is defined by The World Health Organization (WHO) as the stage between the ages of 10 and 19. They normally divide it into two phases; early adolescence from 12 to 14 years old and late adolescence from 15 to 19 years old (WHO, 2022).

In each of these stages, there are physiological changes (stimulation and functioning of the organs by hormones, female and male), structural (anatomical), psychological (integration of personality and identity), and adaptation to cultural and/or social changes (SSA, 2015).

On the other side, the United Nations Children's Fund (UNICEF, 2015) points out that both adolescence and youth are periods of opportunities and changes during which adolescents and young people develop their capacities to learn, experiment, use critical thinking, express their creative freedom and participate in social and political processes, so ensuring the full development of these capacities must be a common priority for all societies.

Adolescents have been a subject open to research and an object of concern for social scientists, educators, parents, and civic and political institutions, but so are their research strategies and methods, both qualitative and quantitative. This is how the modern treatment of adolescence is a field of study for anthropology, psychology, developmental biology, sociology, and history (Lozano, 2014).

In the field of psychology there are many books and studies, for example, in Aguirre (1994) this stage was studied from the cultural, biological, gender identity, corporeality, sexuality, affective development, cognitive development, the experience of the socio-family group, socialization, relationships with their parents, ideology and values, access to work, among others. At the neuropsychological level, adolescents have been studied from various angles, they have gone from a clinical perspective as psychiatric patients (Allott, et al., 2013) also around their emotions (Orón, 2014) or from their executive functions in relation to their sexual behavior (Morais, et al., 2016) and their eating behavior (Herbrich, et al., 2019) to their relationship between anxiety and attention, working memory among other tasks in the performance of its operation (Jarros, et al., 2017).

Working memory is the system that maintains a limited set of representations for immediate use in cognition, it is a central part of human cognition (Ricker, et al., 2018). The term "working memory" evolved from the earlier concept of short-term memory, and the two are still sometimes used interchangeably. But it is safe to say that the popularity of the concept of working memory owes much to neurobiological studies that seem to suggest that it may depend on one or more specific anatomical locations. There are many theories that address this concept such as Cowan's integrated process theory, Daneman and Carpenter's individual difference-based theories, Jonides' mind and brain, computational models (Baddeley, 2012).

Working memory is one of the cognitive constructs with the greatest influence and attention it has received in recent years. It can be defined as the ability to temporarily keep information active for use in different cognitive activities such as understanding or thinking (Pelegrina, et al., 2016).

Working memory is essential for learning, language understanding, reasoning, problema-solving, planning, and categorization. It is even difficult to think of any complex cognitive task that does not require the use of working memory (Ramos, et al., 2007).

The development of the concept of a single memory system to a system of more components in working memory has been very advantageous, both in theoretical and applied research. In this way, the importance of working memory is clarified by translating it as a general system of cognitive control and executive processing that indicates behavior and that implies interactions between the different processes of the mind such as attention, perception, motivation, and memory (López, 2011).

In relation to attention, it facilitates objective processing during perceptual and post perceptual stages, and functionally dissociated processes have been implicated in maintaining different types of information in working memory (AWH, et al., 2006).

As said before, adolescents do not always feel motivated to practice mindfulness, so the aim of this work consists in proposing a mindfulness intervention through the use of a virtual reality headset that allows access to mindfulness training in a way that is more attractive to them, evidencing the favorable effects on attention and working memory of the participants.

Method

Study design

In the present study, was used an experimental study of two groups repeated measures design (T_1 =pretest, T_2 = posttest) (Roberts & Ilardi, 2003) to evaluate the effect of a Mindfulness intervention with virtual reality (MIVR) on divided attention (DA) and working memory (WM).

Participants

Volunteer adolescents, summoned through a social network (Facebook), from the city of Tepic, Nayarit, Mexico. Individuals who were interested in participating received detailed study information and a written informed consent form for the tutors.

Inclusion criteria.

Adolescents aged between 14 and 17 years old, who had the permission of their tutor, who was not used to using virtual reality (VR) or the Oculus Rift S headset, who had not previously practiced mindfulness, who did not report vision problems, with Level B2 Cambridge English.

Exclusion criteria.

People who did not agree to participate in the study or those who did not complete the two consecutive measurements in time (T_1 =pretest, and T_2= posttest).

Study setting

The intervention was carried out in a psychotherapy office owned by the researcher, located in the city of Tepic, Nayarit, México.

Procedure

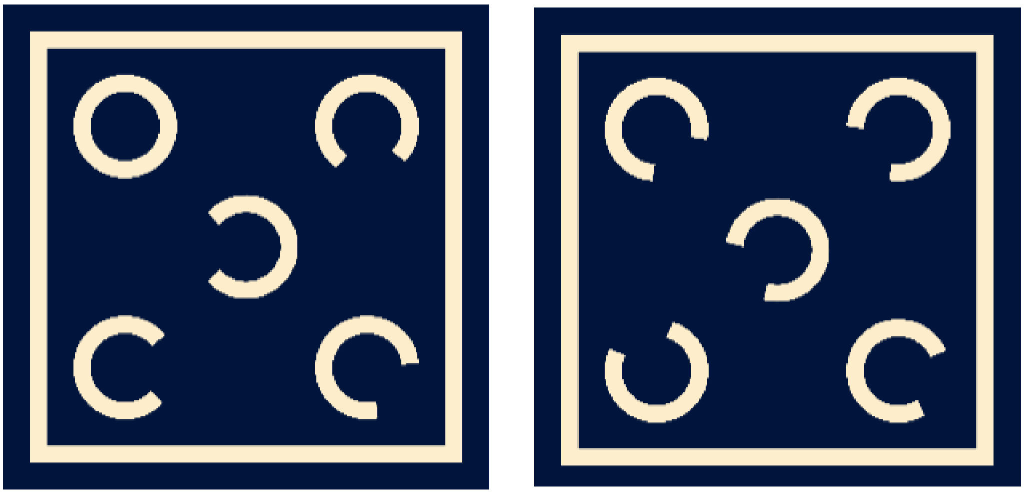
The adolescents were individually scheduled together with their tutor to evaluate divided attention and working memory through the RehaCom software, with a pretest duration of 20 minutes. For the intervention, the participants attended the appointment in groups of 5 people. The headset was placed on them and later, after 5 minutes of habituation, the app whose guided mindfulness meditation lasted 7 minutes was started. In the end, they were allowed to stay 3 minutes of immersion. The intervention was carried out from Monday to Saturday for 21 days. At the end of which, the participants were individually called again for their second evaluation.

Outcome's variables

Measures of divided attention (DA) and working memory (WM) were evaluated with the RehaCom Screening Test, a well-identified instrument used in previous research (Amonn, et al., 2013; Flavia, et al., 2010; Zahraa, et al., 2021). It consists of 9 modules for screening the cognitive status of people with neurological and/or psychiatric diseases but also is used in healthy subjects.

For DA, the client has to solve a visual and an auditive task-parallel simultaneously in one trial. One trial contains 80 visual stimuli with about 15% relevant stimuli as well as 160 auditive stimuli with approximately 10% relevant stimuli. For a visual as well as an auditive stimulus, the client has to push the same button on the keyboard. Both tasks start at the same time. (See Figure 1). For the Divided Attention screening module, two Z-values are calculated, Z-values 1 (Auditive divided attention), the standard value is the number of auditive omissions; meaning the number of missed reactions to two consecutive, identical acoustic stimuli. Z-values 2 (Visual divided attention), the standard value is the number of visual omissions; meaning: the number of missed reactions to a relevant visual stimulus (Hasomed, 2022).

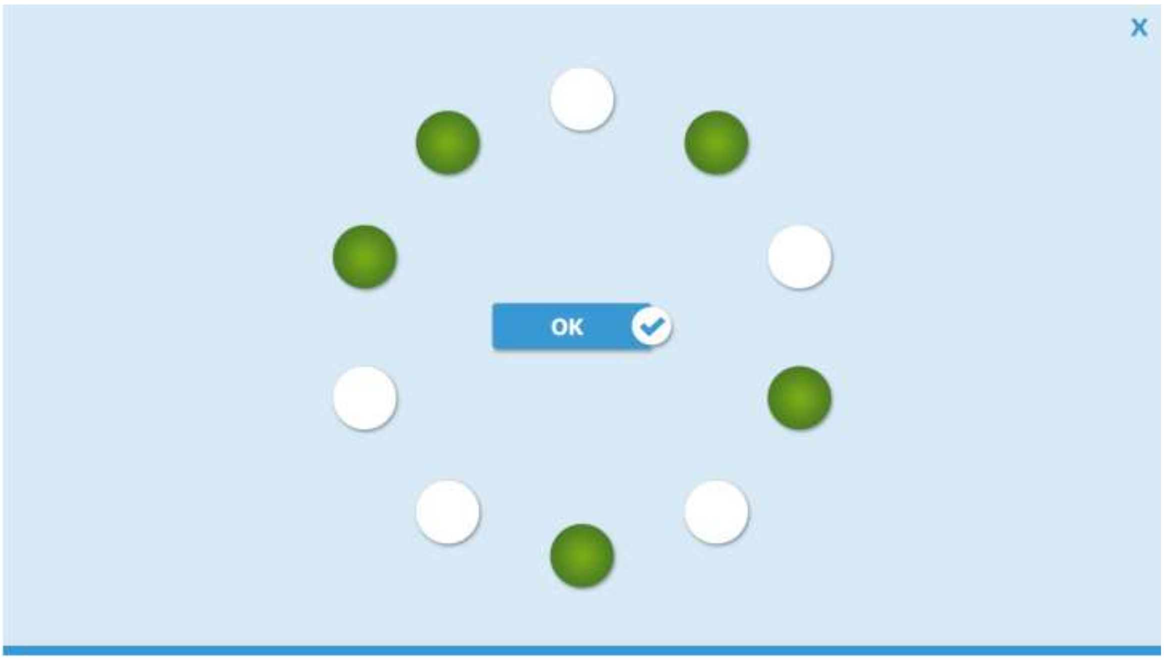
Figure 1. Screening of Divided Attention



Source: Hasomed, 2022

For WM, the screening is similar to the classic Corsi-Block-Tapping. Individual dots sequentially turn red and fade. The first sequence consists of two random dots out of the 10 lighting up in a particular order. After the sequence is presented, the patient must select the same dots in the same order as they were presented. Each sequence is new, meaning sequences do not repeat the previous sequence. If the patient selects a sequence of dots correctly, the number of dots increases in the next sequence. The task is to register and memorize the presented sequence of dots lighting up. The patient should try to memorize the sequence and position of the red dots and to reproduce them. The program is adaptive, adjusting the difficulty according to the performance of the client. If the patient makes a mistake, the degree of difficulty is reduced. The screening ends after the patient incorrectly reproduces two consecutive sequences or after 7 minutes (See Figure 2). In the Working Memory screening module, one Z-value is calculated. Z-value: Memory span The patient's memory span is based on the highest sequence length measured in number of dots, reproduced without mistakes in position and order. The memory span must be confirmed by completing two consecutive sequences with the same number of dots (Hasomed, 2022).

Figure 2. Screening of Working Memory



Source: Hasomed, 2022

Tools

Oculus Rift S. The Oculus Rift S device is a Head-mounted display (HMD), which is used to project an immersive virtual reality in front of the user and allows them to focus on the screen without distractions. A magnetic sensor inside the HMD detects the user's head movement and sends that information to the attached processor. Consequently, the user turns his head; the displayed graphics can reflect the changing point of view, which allows an immersive experience in virtual reality designed for video games (Facebook, 2014).

TRIPP VR Meditation App. Include guided meditations with immersive mindfulness teachings. TRIPP® works with neuroscience and psychiatric advisors to inform its product development and design choices as well as approaches on how to work effectively with researchers and clinicians focused on the category of digital therapeutics (Schrempf, et al., 2021). It was used version 1.0.2744.2939 in English (Tripp, 2022).

Statistical analyses

Were used three Mixed Model ANOVA, one for DividedattentionAuditivePretest and DividedattentionauditivePosttest by Group and Sex; The second Mixed Model ANOVA for DividedattentionvisualPretest and DividedattentionvisualPosttest by Group and Sex; a thord Mixed Model ANOVA for WorkingMemoryPretest and WorkingMemoryPosttest by Group and Sex.

Ethical considerations

This study is considered a minimal risk investigation, in accordance with Article 17 of the Mexican General Law of Health in Research Matters for Health (Diario Oficial de la Federacion, 1987), because it involved a psychological procedure in human beings. The authors based their application of moral rules and professional codes of conduct according to the recommendations for Conduct, Reports, Edition, and Publication of Academic Papers in Medical Journals (ICMJE, 2019).

Results

Mixed Model ANOVA 1

Introduction

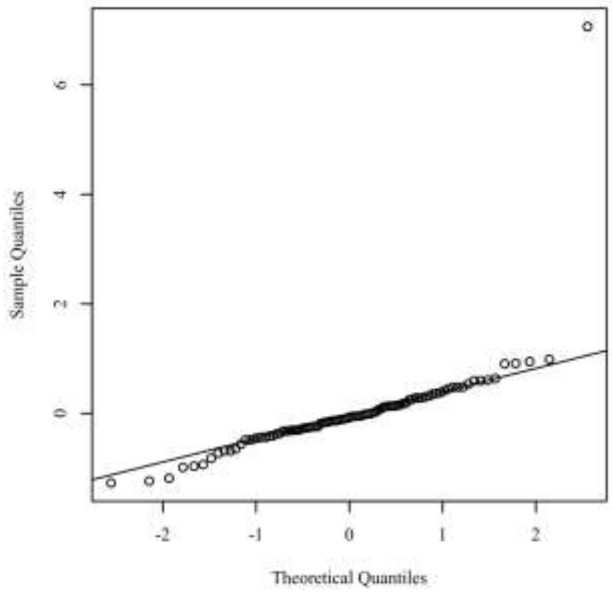
A mixed model analysis of variance (ANOVA) with one within-subjects factor and two between-subjects factors was conducted to determine whether significant differences exist among DividedattentionAuditivePretest and DividedattentionauditivePosttest between the levels of Group and Sex.

Assumptions

Normality. The assumption of normality was assessed by plotting the quantiles of the model residuals against the quantiles of a Chi-square distribution, also called a Q-Q scatterplot (DeCarlo, 1997). For the assumption of normality to be met, the quantiles of the residuals must not strongly deviate from the theoretical quantiles. Strong deviations could indicate that the parameter estimates are unreliable. Figure 3 presents a Q-Q scatterplot of model residuals.

Figure 3

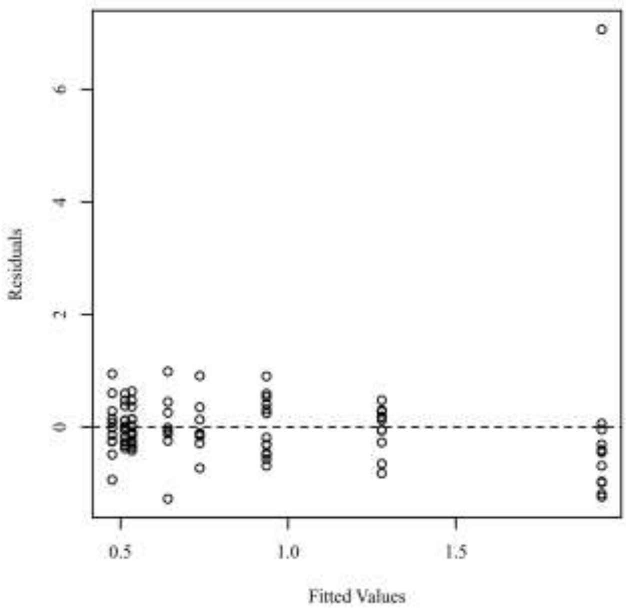
Q-Q scatterplot for normality of the residuals for the regression model.



Homoscedasticity. Homoscedasticity was evaluated by plotting the residuals against the predicted values (Bates et al., 2014; Field, 2017; Osborne & Walters, 2002). The assumption of homoscedasticity is met if the points appear randomly distributed with a mean of zero and no apparent curvature. Figure 4 presents a scatterplot of predicted values and model residuals.

Figure 4

Residuals scatterplot testing homoscedasticity



Sphericity. The usual sphericity assumption does not apply when there are only two repeated measurements.

Multivariate Outliers. To identify influential points in the residuals, Mahalanobis distances were calculated and compared to a χ^2

distribution (Newton & Rudestam, 2012). An outlier was defined as any Mahalanobis distance that exceeds 13.82, the 0.999 quantile of a χ^2 distribution with 2 degrees of freedom (Kline, 2015). There were 1 observations detected as outliers.

Results

The results were examined based on an alpha of .05. The main effect for Group was significant, $F(1, 43) = 7.40$, $p = .009$, indicating that there were significant differences in DividedattentionAuditivePretest and DividedattentionauditivePosttest between the levels of Group. The main effect for Sex was not significant, $F(1, 43) = 0.95$, $p = .336$, indicating the levels of Sex were all similar for DividedattentionAuditivePretest and DividedattentionauditivePosttest. The main effect for the within-subjects factor was significant, $F(1, 43) = 7.07$, $p = .011$, indicating there were significant differences between the values of DividedattentionAuditivePretest and DividedattentionauditivePosttest. The interaction effect between the within-subjects factor and Group was significant, $F(1, 43) = 5.47$, $p = .024$, indicating that the relationship between DividedattentionAuditivePretest and DividedattentionauditivePosttest differed significantly between the levels of Group. The interaction effect between the within-subjects factor and Sex was not significant, $F(1, 43) = 0.03$, $p = .867$, indicating that the relationship between DividedattentionAuditivePretest and DividedattentionauditivePosttest was similar between the levels of Sex. Table 1 presents the ANOVA results.

Table 1

Mixed Model ANOVA Results

Source	*df*	*SS*	*MS*	*F*	*p*	η_p^2
Between-Subjects						
Group	1	6.78	6.78	7.40	.009	0.15
Sex	1	0.87	0.87	0.95	.336	0.02
Group:Sex	1	2.93	2.93	3.20	.081	0.07
Residuals	43	39.40	0.92			
Within-Subjects						
Within Factor	1	5.17	5.17	7.07	.011	0.14
Group:Within.Factor	1	4.00	4.00	5.47	.024	0.11
Sex:Within.Factor	1	0.02	0.02	0.03	.867	0.0007
Group:Sex:Within.Factor	1	0.10	0.10	0.14	.710	0.003
Residuals	43	31.40	0.73			

Post-hoc. The mean contrasts utilized Tukey comparisons based on an alpha of .05. Tukey comparisons were used to test the differences in the estimated marginal means for each combination of between-subject and within-subject effects.

Between Effects. For the Experimental category of Group, DividedattentionAuditivePretest was significantly less than DividedattentionauditivePosttest, $t(43) = -3.73$, $p < .001$. No other significant differences were found for Group. For the Woman category of Sex, DividedattentionAuditivePretest was significantly less than DividedattentionauditivePosttest, $t(43) = -2.19$, $p = .034$. No other significant differences were found for Sex. Table 2 presents the marginal means contrasts for the Mixed Model ANOVA.

Table 2

The Marginal Means Contrasts for each Combination of Within-Subject Variables for the Mixed Model ANOVA

Contrast	Difference	*SE*	*df*	*t*	*p*
Group|Control					
DividedattentionAuditivePretest - DividedattentionauditivePosttest	-0.06	0.27	43	-0.22	.830
Group|Experimental					
DividedattentionAuditivePretest - DividedattentionauditivePosttest	-0.90	0.24	43	-3.73	< .001
Sex|Man					
DividedattentionAuditivePretest - DividedattentionauditivePosttest	-0.45	0.28	43	-1.63	.110
Sex|Woman					
DividedattentionAuditivePretest - DividedattentionauditivePosttest	-0.51	0.23	43	-2.19	.034

Note. Tukey Comparisons were used to test the differences in estimated marginal means.

Between Effect Interactions. For the combination of the Man category of Sex and the Experimental category of Group, DividedattentionAuditivePretest was significantly less than DividedattentionauditivePosttest, $t(43) = -2.31$, $p = .026$. For the combination of the Woman category of Sex and the Experimental category of Group, DividedattentionAuditivePretest was significantly less than DividedattentionauditivePosttest, $t(43) = -2.98$, $p = .005$. No other significant differences were found for the interaction between Sex:Group. Table 3 presents the marginal means contrasts for each combination of the between effect interactions and within-subjects factor.

Table 3

The Marginal Means Contrasts for each Combination of the Between-Subject Interactions and Within-Subject Factor for the Mixed Model ANOVA

Contrast	Difference	*SE*	*df*	*t*	*p*
Sex|Man:Group|Control					
DividedattentionAuditivePretest - DividedattentionauditivePosttest	-0.09	0.43	43	-0.22	.825
Sex|Woman:Group|Control					

DividedattentionAuditivePretest - DividedattentionauditivePosttest	-0.02	0.32	43	-0.06	.950
Sex|Man:Group|Experimental					
DividedattentionAuditivePretest - DividedattentionauditivePosttest	-0.80	0.35	43	-2.31	.026
Sex|Woman:Group|Experimental					
DividedattentionAuditivePretest - DividedattentionauditivePosttest	-1.00	0.34	43	-2.98	.005

Note. Tukey Comparisons were used to test the differences among estimated marginal means.

Mixed Model ANOVA 2

Introduction

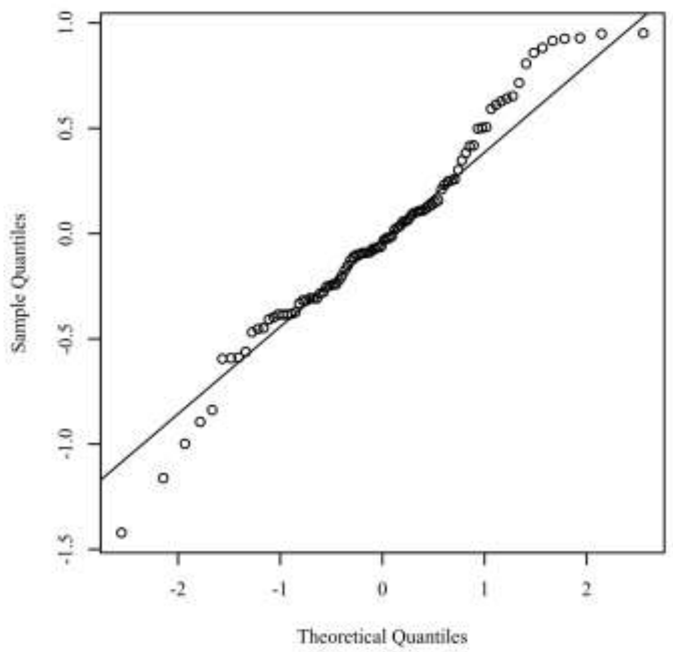
A mixed model analysis of variance (ANOVA) with one within-subjects factor and two between-subjects factors was conducted to determine whether significant differences exist among DividedattentionvisualPretest and DividedattentionvisualPosttest between the levels of Group and Sex.

Assumptions

Normality. The assumption of normality was assessed by plotting the quantiles of the model residuals against the quantiles of a Chi-square distribution, also called a Q-Q scatterplot (DeCarlo, 1997). For the assumption of normality to be met, the quantiles of the residuals must not strongly deviate from the theoretical quantiles. Strong deviations could indicate that the parameter estimates are unreliable. Figure 5 presents a Q-Q scatterplot of model residuals.

Figure 5

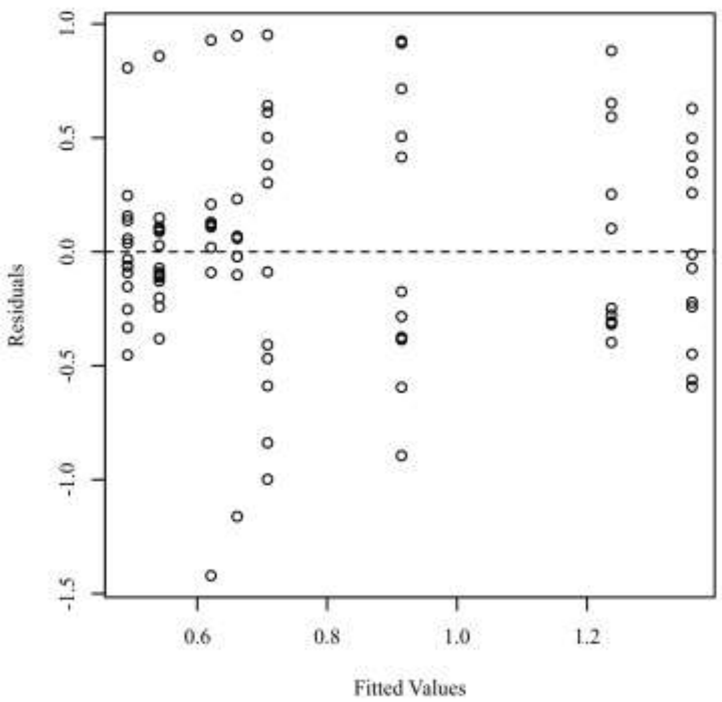
Q-Q scatterplot for normality of the residuals for the regression model.



Homoscedasticity. Homoscedasticity was evaluated by plotting the residuals against the predicted values (Bates et al., 2014; Field, 2017; Osborne & Walters, 2002). The assumption of homoscedasticity is met if the points appear randomly distributed with a mean of zero and no apparent curvature. Figure 6 presents a scatterplot of predicted values and model residuals.

Figure 6

Residuals scatterplot testing homoscedasticity



Sphericity. The usual sphericity assumption does not apply when there are only two repeated measurements.

Multivariate Outliers. To identify influential points in the residuals, Mahalanobis distances were calculated and compared to a χ^2 distribution (Newton & Rudestam, 2012). An outlier was defined as any Mahalanobis distance that exceeds 13.82, the 0.999 quantile of a χ^2 distribution with 2 degrees of freedom (Kline, 2015). There were no outliers detected in the model.

Results

The results were examined based on an alpha of .05. The main effect for Group was significant, $F(1, 43) = 11.27$, $p = .002$, indicating that there were significant differences in DividedattentionvisualPretest and DividedattentionvisualPosttest between the levels of Group. The main effect for Sex was not significant, $F(1, 43) = 0.09$, $p = .771$, indicating the levels of Sex were all similar for DividedattentionvisualPretest and DividedattentionvisualPosttest. The interaction effect between Group and Sex was not significant $F(1, 43) = 0.34$, $p = .563$, indicating there were no significant differences in DividedattentionvisualPretest and DividedattentionvisualPosttest for each factor level combination of Group and Sex. The main effect for the within-subjects factor was significant, $F(1, 43) = 41.40$, $p < .001$, indicating there were significant differences between the values of DividedattentionvisualPretest and DividedattentionvisualPosttest. The interaction effect between the within-subjects factor and Group was significant, $F(1, 43) = 28.70$, $p < .001$, indicating that the relationship between DividedattentionvisualPretest and DividedattentionvisualPosttest differed significantly between the levels of Group. The interaction effect between the within-subjects factor and Sex was not significant, $F(1, 43) = 3.78$, $p = .058$, indicating that the relationship between DividedattentionvisualPretest and DividedattentionvisualPosttest was similar between the levels of Sex. The interaction effect between the within-subjects factor, Group, and Sex was significant $F(1, 43) = 4.19$, $p = .047$, indicating that the relationship differed significantly between the factor level combinations of Group and Sex. Table 4 presents the ANOVA results.

Table 4

Mixed Model ANOVA Results

Source	*df*	*SS*	*MS*	*F*	*p*	η_p^2
Between-Subjects						
Group	1	5.09	5.09	11.27	.002	0.21
Sex	1	0.04	0.04	0.09	.771	0.002
Group:Sex	1	0.15	0.15	0.34	.563	0.008
Residuals	43	19.41	0.45			
Within-Subjects						
Within Factor	1	1.59	1.59	41.40	< .001	0.49
Group:Within.Factor	1	1.10	1.10	28.70	< .001	0.40
Sex:Within.Factor	1	0.15	0.15	3.78	.058	0.08
Group:Sex:Within.Factor	1	0.16	0.16	4.19	.047	0.09
Residuals	43	1.65	0.04			

Post-hoc. The mean contrasts utilized Tukey comparisons based on an alpha of .05. Tukey comparisons were used to test the differences in the estimated marginal means for each combination of between-subject and within-subject effects.

Between Effects. For the Experimental category of Group, DividedattentionvisualPretest was significantly less than DividedattentionvisualPosttest, $t(43) = -8.80$, $p < .001$. No other significant differences were found for Group. For the Man category of Sex, DividedattentionvisualPretest was significantly less than DividedattentionvisualPosttest, $t(43) = -5.48$, $p < .001$. For the Woman category of Sex, DividedattentionvisualPretest was significantly less than DividedattentionvisualPosttest, $t(43) = -3.48$, $p = .001$. Table 5 presents the marginal means contrasts for the Mixed Model ANOVA.

Table 5

The Marginal Means Contrasts for each Combination of Within-Subject Variables for the Mixed Model ANOVA

Contrast	Difference	*SE*	*df*	*t*	*p*
Group|Control					

DividedattentionvisualPretest - DividedattentionvisualPosttest	-0.04	0.06	43	-0.73	.472
Group|Experimental					
DividedattentionvisualPretest - DividedattentionvisualPosttest	-0.49	0.06	43	-8.80	< .001
Sex|Man					
DividedattentionvisualPretest - DividedattentionvisualPosttest	-0.35	0.06	43	-5.48	< .001
Sex|Woman					
DividedattentionvisualPretest - DividedattentionvisualPosttest	-0.19	0.05	43	-3.48	.001

Note. Tukey Comparisons were used to test the differences in estimated marginal means.

Between Effect Interactions. For the combination of the Experimental category of Group and the Man category of Sex, DividedattentionvisualPretest was significantly less than DividedattentionvisualPosttest, $t(43) = -8.16$, $p < .001$. For the combination of the Experimental category of Group and the Woman category of Sex, DividedattentionvisualPretest was significantly less than DividedattentionvisualPosttest, $t(43) = -4.20$, $p < .001$. No other significant differences were found for the interaction between Group:Sex. Table 6 presents the marginal means contrasts for each combination of the between effect interactions and within-subjects factor.

Table 6

The Marginal Means Contrasts for each Combination of the Between-Subject Interactions and Within-Subject Factor for the Mixed Model ANOVA

Contrast	Difference	*SE*	*df*	*t*	*p*
Group|Control:Sex|Man					
DividedattentionvisualPretest - DividedattentionvisualPosttest	-0.04	0.10	43	-0.41	.683
Group|Experimental:Sex|Man					
DividedattentionvisualPretest - DividedattentionvisualPosttest	-0.65	0.08	43	-8.16	< .001
Group|Control:Sex|Woman					
DividedattentionvisualPretest - DividedattentionvisualPosttest	-0.05	0.07	43	-0.66	.514
Group|Experimental:Sex|Woman					
DividedattentionvisualPretest - DividedattentionvisualPosttest	-0.32	0.08	43	-4.20	< .001

Note. Tukey Comparisons were used to test the differences in estimated marginal means.

Mixed Model ANOVA 3

Introduction

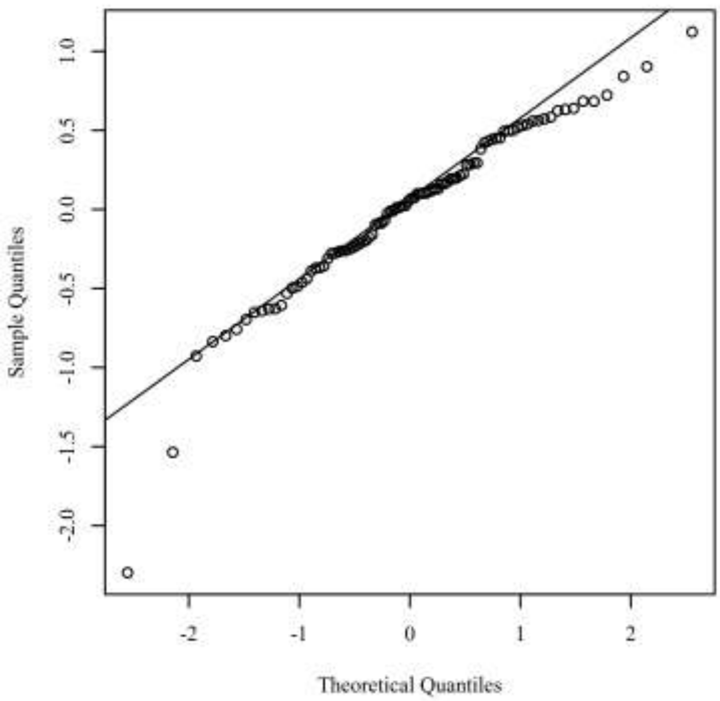
A mixed model analysis of variance (ANOVA) with one within-subjects factor and two between-subjects factors was conducted to determine whether significant differences exist among WorkingMemoryPretest and WorkingMemoryPosttest between the levels of Group and Sex.

Assumptions

Normality. The assumption of normality was assessed by plotting the quantiles of the model residuals against the quantiles of a Chi-square distribution, also called a Q-Q scatterplot (DeCarlo, 1997). For the assumption of normality to be met, the quantiles of the residuals must not strongly deviate from the theoretical quantiles. Strong deviations could indicate that the parameter estimates are unreliable. Figure 7 presents a Q-Q scatterplot of model residuals.

Figure 7

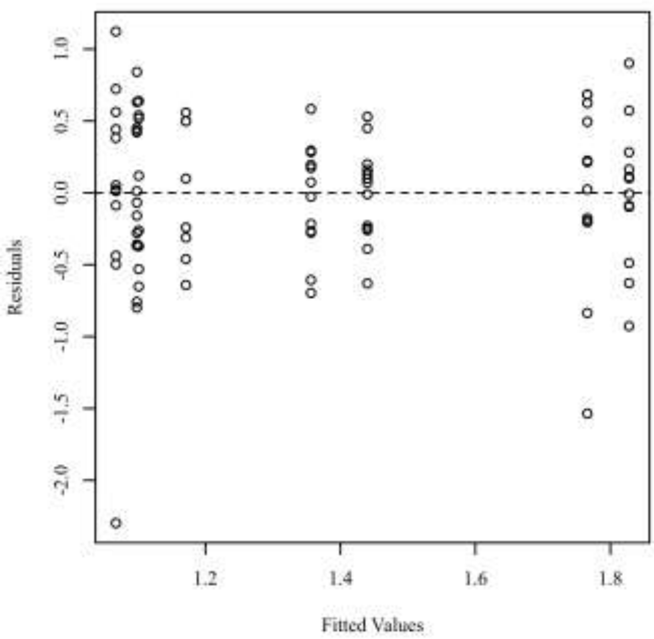
Q-Q scatterplot for normality of the residuals for the regression model.



Homoscedasticity. Homoscedasticity was evaluated by plotting the residuals against the predicted values (Bates et al., 2014; Field, 2017; Osborne & Walters, 2002). The assumption of homoscedasticity is met if the points appear randomly distributed with a mean of zero and no apparent curvature. Figure 8 presents a scatterplot of predicted values and model residuals.

Figure 8

Residuals scatterplot testing homoscedasticity



Sphericity. The usual sphericity assumption does not apply when there are only two repeated measurements.

Multivariate Outliers. To identify influential points in the residuals, Mahalanobis distances were calculated and compared to a χ^2 distribution (Newton & Rudestam, 2012). An outlier was defined as any Mahalanobis distance that exceeds 13.82, the 0.999 quantile of a χ^2 distribution with 2 degrees of freedom (Kline, 2015). There were 1 observations detected as outliers.

Results

The results were examined based on an alpha of .05. The main effect for Group was not significant, $F(1, 43) = 1.20$, $p = .279$, indicating the levels of Group were all similar for WorkingMemoryPretest and WorkingMemoryPosttest. The main effect for Sex was not significant, $F(1, 43) = 0.96$, $p = .333$, indicating the levels of Sex were all similar for WorkingMemoryPretest and WorkingMemoryPosttest. The interaction effect between Group and Sex was not significant $F(1, 43) = 0.47$, $p = .498$, indicating there were no significant differences in WorkingMemoryPretest and WorkingMemoryPosttest for each factor level combination of Group and Sex. The main effect for the within-subjects factor was significant, $F(1, 43) = 89.95$, $p < .001$, indicating there were significant differences between the values of WorkingMemoryPretest and WorkingMemoryPosttest. The interaction effect between the within-subjects factor and Group was significant, $F(1, 43) = 58.40$, $p < .001$, indicating that the relationship between WorkingMemoryPretest and WorkingMemoryPosttest differed significantly between the levels of Group. The interaction effect between the within-subjects factor and Sex was not significant, $F(1, 43) = 0.07$, $p = .791$, indicating that the relationship between WorkingMemoryPretest and WorkingMemoryPosttest was similar between the levels of Sex. The interaction effect between the within-subjects factor and Group:Sex was not significant $F(1, 43) = 0.01$, $p = .918$, indicating that the relationship between WorkingMemoryPretest and WorkingMemoryPosttest was similar between the factor level combinations of Group and Sex. Table 7 presents the ANOVA results.

Table 7

Mixed Model ANOVA Results

Source	*df*	*SS*	*MS*	*F*	*p*	η_p^2
Between-Subjects						
Group	1	0.67	0.67	1.20	.279	0.03
Sex	1	0.53	0.53	0.96	.333	0.02
Group:Sex	1	0.26	0.26	0.47	.498	0.01
Residuals	43	23.95	0.56			
Within-Subjects						
Within Factor	1	3.50	3.50	89.95	< .001	0.68
Group:Within.Factor	1	2.28	2.28	58.40	< .001	0.58
Sex:Within.Factor	1	0.003	0.003	0.07	.791	0.002
Group:Sex:Within.Factor	1	0.0004	0.0004	0.01	.918	0.0002
Residuals	43	1.68	0.04			

Post-hoc. The mean contrasts utilized Tukey comparisons based on an alpha of .05. Tukey comparisons were used to test the differences in the estimated marginal means for each combination of between-subject and within-subject effects.

Between Effects. For the Experimental category of Group, WorkingMemoryPretest was significantly less than WorkingMemoryPosttest, $t(43) = -12.77$, $p < .001$. No other significant differences were found for Group. For the Man category of Sex, WorkingMemoryPretest was significantly less than WorkingMemoryPosttest, $t(43) = -6.03$, $p < .001$. For the Woman category of Sex, WorkingMemoryPretest was significantly less than WorkingMemoryPosttest, $t(43) = -7.56$, $p < .001$. Table 8 presents the marginal means contrasts for the Mixed Model ANOVA.

Table 8

The Marginal Means Contrasts for each Combination of Within-Subject Variables for the Mixed Model ANOVA

Contrast	Difference	*SE*	*df*	*t*	*p*
Group|Control					
WorkingMemoryPretest - WorkingMemoryPosttest	-0.08	0.06	43	-1.24	.221
Group|Experimental					
WorkingMemoryPretest - WorkingMemoryPosttest	-0.71	0.06	43	-12.77	< .001
Sex|Man					
WorkingMemoryPretest - WorkingMemoryPosttest	-0.38	0.06	43	-6.03	< .001
Sex|Woman					

WorkingMemoryPretest - WorkingMemoryPosttest	-0.41	0.05	43	-7.56	< .001

Note. Tukey Comparisons were used to test the differences in estimated marginal means.

Between Effect Interactions. For the combination of the Experimental category of Group and the Man category of Sex, WorkingMemoryPretest was significantly less than WorkingMemoryPosttest, $t(43) = -8.67$, $p < .001$. For the combination of the Experimental category of Group and the Woman category of Sex, WorkingMemoryPretest was significantly less than WorkingMemoryPosttest, $t(43) = -9.42$, $p < .001$. No other significant differences were found for the interaction between Group:Sex. Table 9 presents the marginal means contrasts for each combination of the between effect interactions and within-subjects factor.

Table 9

The Marginal Means Contrasts for each Combination of the Between-Subject Interactions and Within-Subject Factor for the Mixed Model ANOVA

Contrast	Difference	*SE*	*df*	*t*	*p*
Group|Control:Sex|Man					
WorkingMemoryPretest - WorkingMemoryPosttest	-0.07	0.10	43	-0.71	.482
Group|Experimental:Sex|Man					
WorkingMemoryPretest - WorkingMemoryPosttest	-0.70	0.08	43	-8.67	< .001
Group|Control:Sex|Woman					
WorkingMemoryPretest - WorkingMemoryPosttest	-0.08	0.07	43	-1.12	.269
Group|Experimental:Sex|Woman					
WorkingMemoryPretest - WorkingMemoryPosttest	-0.73	0.08	43	-9.42	< .001

Note. Tukey Comparisons were used to test the differences in estimated marginal means.

Conclusion and Discussion

The aim of this work consisted in proposing a mindfulness intervention through the use of a virtual reality headset that allows access to mindfulness training in a way that is more attractive to adolescents, evidencing the favorable effects on attention and working memory of the participants.

The results showed that there was a significant difference between the experimental and control groups between measurements (T_2 T_1), in terms of divided attention (auditive and visual) and working memory (p <0.001), but there were no differences between man and woman, suggesting a significant improvement in 21 days of MIVR.

The impact of virtual reality in the field of education and technology, when used for learning, can produce favorable effects on cognitive abilities, by producing presence and a stronger immersion experience (Budhwani, et al., 2021; Parsons, et al., 2017; Blume, et al., 2017), a tool that strengthens interventions of any kind, especially mindfulness (Yuan, 2021; Hillhouse, et al., 2021; Miller, et al., 2021). This research corroborates and contributes to a better understanding of the direct effects on this Virtual Reality and mindfulness interaction, also verifying that adherence to monitoring the process gives evidence of the motivation acquired by adolescents.

It could be interesting in a subsequent investigation to compare this intervention against one that does not use virtual reality, because although the effects on divided attention and working memory could be verified, as a second step, a comparative study could be carried out that allows expanding the intervention options in adolescents.

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