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Effectiveness of Virtual Reality for Pediatric Pain and Anxiety Management during Skin Prick Testing

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Abstract

This study investigated the effectiveness of virtual reality (VR) distraction, compared to comic book distraction and no distraction, in reducing pain and anxiety during a medical procedure in a pediatric population: the skin prick test. Although this test has many advantages and is considered to be minimally invasive, it causes anxiety and painful discomfort in children. Ninety-two children aged 7 to 17 years consulting for an allergic test received VR distraction, comic book distraction, or no distraction. Outcome measures included pain score, level of anxiety, and VR measures. The results showed that there were no significant differences between the three groups regarding sex, age, and preprocedural anxiety level. In the distraction groups (VR and comic book), children reported significantly lower pain and procedural anxiety scores than children with no distraction; VR distraction had a more significant effect than comic book distraction. A decrease in anxiety before and during the skin prick test is significantly more significant in VR distraction. This study suggested the effectiveness and feasibility of VR to reduce pain and anxiety during the pediatric skin prick test.

Keywords

Pain, Anxiety, Virtual Reality, Children, Skin Prick Testing

1. Introduction

Pain is "an unpleasant sensory and emotional experience associated with actual or potential tissue damage, or described in terms of such damage" [1]. Many

medical procedures provoke pain, and in consequence, anxiety, and distress in children [2] [3]. For several years, pediatric health establishments have been mobilizing to manage this pain better.

Pharmacological interventions for the treatment of pain in children are based on the use of drugs, such as pain relievers to reduce symptoms. Although the pharmacological approach has shown its effectiveness [4] [5], best practice guidelines conclude that isolated medical interventions are not sufficient; in some cases, they can prove counterproductive [6] [7]. On the other hand, the biopsychosocial model of pain suggests that it is influenced by cognitive, affective, and behavioral factors that determine its management and consequences, at least in part [8] [9].

The theory of parallel information processing [10] postulates that the subjective experience of pain results from complex information processing that considers several factors: 1) sensory and emotional experience, 2) cognitive interpretation, 3) expectations, and 4) beliefs. Indeed, in recent years, researchers have attributed increasing importance to attention, fear of pain, and memories of painful events in the sensory and affective experience of pain [11] [12] [13] As this theory suggests, attention plays a significant role in the experience of pain; it can increase the subjective perception of pain, which is moderated by the subject's cognitive and emotional interpretation of the pain. According to Melzack and Wall [14], any distracting task or activity that has the potential to divert attention from pain could therefore lead to a reduction, or even an inhibition, of pain. Moreover, distraction strategies effectively reduce the experience of a painful stimulus or reduce its harmful effects by directing the attention consumed by the painful stimulus to another source of stimulation [15] [16]. Several studies have demonstrated the effectiveness of a distracting task, such as music, video games, movies, reading, etc., in decreasing the experience of pain [17] [18].

For a task to constitute a potential distractor, diverting attention to something other than pain, the individual must consciously and continuously focus on the activity in question [19] [20]. In this sense, virtual reality (VR) seems to represent an attractive option since it uses computer technology to immerse the individual in a multisensory, three-dimensional environment [21]. Therefore, it should make it possible to combine the desired distraction effect with a high degree of attention generated by a task that the subject has to perform [19] [20]. Thus, the emergence of new technologies, particularly the use of VR (3D), is opening up new perspectives for the management of acute pediatric pain.

The use of VR as a therapeutic tool for managing acute pain has already proven effective in several areas through its potential distractor effect. The results of several meta-analyses [22] [23] demonstrate the effectiveness of VR at reducing pediatric pain during a medical procedure in oncology [24] [25], burn care [26] [27], intravenous placement [28] [29] [30] [31], and the emergency room [32].

The use of skin prick tests is considered a gold standard in the evaluation of allergic reactions. These tests involve depositing a drop or small amount of the allergen on the skin and pricking the skin to let the allergen penetrate the epidermis [33]. Although this test has many advantages and is considered to be minimally invasive [34], it causes anxiety and painful discomfort for children [35]. Managing pain and anxiety during skin prick testing is essential to prevent long-term adverse effects, especially in the case of future needle-stick interventions [36]. Several distraction methods have been shown to be effective at reducing anxiety and pain during skin prick tests in children [37], including hypnosis [38], music [39], and the presence of clowns [40]. To our knowledge, these studies remain limited and no study has yet investigated the value of VR as a distraction tool in this field.

The objective of this study was to investigate the effectiveness of VR in reducing pain and anxiety during a medical procedure in a pediatric population: the skin prick test. We tested the hypothesis that VR is better at reducing the pain and anxiety associated with the skin prick test procedure than two control conditions: reading a book such as a comic and no distraction.

2. Materials and Methods

2.1. Subjects

The children were recruited by a pediatric pneumo-allergist as part of a consultation for allergic tests (skin prick test). The study sample was composed of 92 children aged 7 to 17 years, M = 10.87 years, SD = 2.52 (48 boys, M = 10.48 years, SD = 2.41; 44 girls, M = 11.29 years, SD = 2.58). The inclusion criteria were being aged 7 to 17 years, speaking French regularly, and requiring a skin prick test.

This survey was carried out between February 2019 and March 2020. The study design and procedure were approved by the Regional Hospital Center (CHR) of Verviers, Belgium. Parents and children were informed about the procedure and the general purpose of the study. All participants took part voluntarily and signed an informed consent form in which they were guaranteed anonymity. They were also informed that they could stop participating at any time without needing to justify the decision. Written informed consent was obtained from the children and their parents.

2.2. Design

Children were randomly assigned to one of three conditions: VR distraction group (n = 29), comic book distraction control group (n = 31), and no distraction control group (n = 32). Random assignments were generated with a random numbers table before recruitment by the researcher. Assignments were concealed until the participants signed the informed consent forms; neither the participant nor the experimenter was blinded to group assignment, given the active nature of the interventions. Before the skin prick test, the children completed the

socio-demographic and anxiety state questionnaires. Children in the VR distraction group began interacting with the virtual environment (VE) 2 minutes prior to the skin prick test and continued playing throughout. The VR equipment used was Oculus Go, with software for a game, developed by Vi-Sense, in which the child tries to hit targets with a bow and arrow. Children played the VR game during the skin prick test for approximately 8 minutes. In the comic book distraction group, the child was invited to read the comic book 2 minutes prior to the skin prick test and continued reading throughout. In the control group, no distraction was offered. After the skin prick test, children were invited to assess their levels of anxiety and pain during the skin prick test; the VR distractor group also responded to the Simulator Sickness Questionnaire and Sense of Presence scale to assess their experience in the VE. The research assistant engaged in the behavior's observation observation of each child's pain during the skin prick test.

2.3. Measures

2.3.1. Numeric Rating Scale

The Numeric Rating Scale (NRS-11) [41] is a self-report pain intensity scale, which uses an 11-point visual analog scale (VAS). Children must say how they would rate their pain on a vertical scale ranging from 0 to 10, where 0 is no pain or hurt and 10 is the most or worst pain. The various reliability and validity parameters for this scale appear satisfactory in child and adolescent populations [42].

2.3.2. Children's Hospital of Eastern Ontario Pain Scale

The Children's Hospital of Eastern Ontario Pain Scale (CHEOPS) [43] is a behavioral observational scale to assess children's pain based on observations of their physical reactions. This scale includes operational definitions for six domains: cry, facial, child verbal, torso, touch, and legs. Each domain is scored on a 3- or 2-point response scale. High score indicates high behavior's response to pain. The various reliability and validity parameters for this scale appear satisfactory in child populations [43] [44].

2.3.3. Mental Readiness Form

The Mental Readiness Form (MRF-3) [45] is an instrument to assess state anxiety with three items using VAS. The first item evaluates the level of worry, ranging from 1 "not at all worried" to 11 "very worried." The second evaluates the level of tension, ranging from 1 "very relaxed" to 11 "very tense." And the last rates the level of confidence, ranging from 1 "confident" to 11 "not at all confident." This scale has satisfactory reliability and validity indices [46].

2.3.4. Questionnaire on the Sense of Presence for Children

The Questionnaire on the Sense of Presence for Children [47] comprises 19 items with 3-point Likert scales used to measure children's degree of presence within a VE. The items are taken from the Child Presence Measure [48] and the Presence Questionnaire [49]. The children's version in French was written and

validated by the UQO Cyberpsychology Laboratory team [47].

2.3.5. Simulator Sickness Questionnaire for Children

The Simulator Sickness Questionnaire for Children [47] is an 11-item instrument with 3-point Likert scales which is used to measure the extent to which children feel simulator sickness due to their immersion in VR (e.g., nausea, eye fatigue, dizziness, etc.). The items in this questionnaire are taken from the Simulator Sickness Questionnaire [50] and the Child Simulator Sickness Questionnaire [48], both of which are frequently used during treatments in a VE. The psychometric properties of this questionnaire have been demonstrated [50]. The children's version in French was written and validated by the UQO Cyberpsychology Laboratory team [47].

2.3.6. Data Analyses

All analyses were done with SPSS v.26. Descriptive statistics were carried out to analyze the participants' sociodemographic variables. To test the group effect on sex, chi-square goodness of fit test was used. To test the group effect on age, worry and tension preprocedural anxiety items, one-way analyses of variance (ANOVAs), parametric tests, were used. Some variables presented a Poisson distribution: the confidence item of preprocedural anxiety, procedural anxiety, pain score, and simulator sickness score. For these variables, Poisson regression analyses were used with a Generalized Linear Model (GLM) to test the group effect [51], and with a Generalized Estimating Equation (GEE) to test repeated measures [52]. GEE is an extension of GLM for the analysis of repeated measures.

3. Results

3.1. Group Comparisons: Baseline Characteristics and Preprocedural Anxiety Scores

The characteristics of children (sex, age, and preprocedural anxiety) in each group are presented in Table 1. No significant difference is observed between the three groups in terms of sex, age, and preprocedural anxiety level, except for the confidence item. Post hoc analyses revealed a significant difference only between the no distraction and VR groups ($p = 0.001$; $p = 0.174$ for difference between no distraction and comic book groups; $p = 0.061$ for difference between comic books and VR groups).

3.2. Group Comparisons: Pain Levels

The mean pain levels for each group are presented in Table 2. A significant difference was observed between groups regarding child-reported pain levels but not observer-reported pain levels.

Post hoc analyses were performed to compare the conditions with each other. For pain levels, significant differences were observed between the no distraction and VR groups ($p < 0.001$), the comic book and VR groups ($p < 0.001$), and the no distraction and comic book groups ($p = 0.036$).

Table 1. Baseline characteristics and preprocedural anxiety scores for the study groups.

		No distraction group (n = 32)	Comic book group (n = 31)	VR group (n = 29)	x^2	p
Sex[a]	Female	14 (43.8%)	16 (48.4%)	14 (48.3%)	0.39	0.821
	Male	18 (56.3%)	15 (51.6%)	15 (51.7%)		
		No distraction group (n = 32)	Comic book group (n = 31)	VR group (n = 29)	F	p
Age[b]		11.13 (2.77)	10.87 (2.26)	10.59 (2.54)	0.34	0.710
Preprocedural anxiety[b]	Worry	3.84 (2.54)	4.65 (3.42)	5.21 (2.72)	1.69	0.191
	Tension	3.38 (2.25)	4.68 (2.52)	4.41 (2.67)	2.43	0.094
		No distraction group (n = 32)	Comic book group (n = 31)	VR group (n = 29)	*Wald*	p
	Confidence	2.84 (2.69)	3.45 (3.22)	4.41 (2.82)	10.566	0.005

Data are represented as numbers[a] (*%*) or means[b] (*SD*) where appropriate.

Table 2. Means (*SD*) and comparison of procedural pain scores for the study groups.

	No distraction group (n = 32)	Comic book group (n = 31)	VR group (n = 29)	*Wald*	p
NRS-11	3.87 (2.21)	2.90 (2.20)	1.28 (1.22)	35.234	<0.001
CHEOPS	6.03 (1.94)	6.16 (1.46)	5.10 (1.37)	3.415	0.181

3.3. Group Comparisons: Anxiety Levels

A first analysis was done to test the difference in levels of procedural anxiety between groups. A significant difference was observed for the worry and tension items, but not for the confidence item (Table 3). Post hoc analyses were performed to compare the groups with each other for worry and tension. Significant differences were observed between the no distraction and VR groups ($p < 0.001$ for worry; $p < 0.001$ for tension), and between the comic book and VR groups ($p < 0.001$ for worry; $p < 0.001$ for tension). No significant difference was observed between the no distraction and comic book groups ($p = 0.173$ for worry; $p = 0.546$ for tension).

To test the difference in pre- and procedural anxiety between groups, interaction analyses were performed (time × group) using a GEE approach. The interaction was significant for worry, tension and confidence (respectively, *Wald* (2) = 80.613, $p < 0.001$; *Wald* (2) = 26.432, $p < 0.001$; *Wald* (2) = 10.055, $p = 0.007$), which means that the decrease in anxiety before and during the skin prick test differed according to group. Post hoc analyses for worry and tension showed a significant decrease in anxiety before and during the prick test for the comic book group (respectively, $p = 0.003$; $p = 0.005$) and the VR group (respectively, $p < 0.001$; $p < 0.001$), but not for the no distraction group (respectively, $p = 0.426$; $p = 0.885$). Post hoc analyses for confidence revealed a significant decrease in

anxiety before and during the skin prick test only for the VR group ($p < 0.001$), but not for the comic book and no distraction groups (respectively, $p = 0.165$; $p = 0.444$). The deltas for the pre- and procedural anxiety differences are shown in Table 4. A greater delta is observed in the VR condition.

3.4. Correlations between Procedural Anxiety and Pain

Pearson correlations revealed significant positive associations among the procedural anxiety variables and child- and observer-reported anxiety levels during the skin prick test (Table 5).

3.5. Simulator Sickness and Sense of Presence in Virtual Environment

None of the children reported simulator sickness following VR exposure. No significant difference was observed between the pre- and post-VR exposure symptom levels, *Wald* (1) = 1.115, $p = 0.291$ (*M* pre-immersion = 1.45, *SD* = 2.08; *M* post-immersion = 1.31, *SD* = 1.95). Children in the VR condition demonstrated a sufficient level of presence/immersion with the intervention (*M* = 23.14, *SD* = 9.31, range = 0 - 38).

Table 3. Means (*SD*) and comparison of procedural anxiety scores for the study groups.

	No distraction group ($n = 32$)	Comic book group ($n = 31$)	VR group ($n = 29$)	*Wald*	*p*
Worry	3.63 (2.12)	3.00 (2.81)	1.45 (0.69)	26.131	<0.001
Tension	3.44 (2.55)	3.16 (2.52)	1.76 (0.91)	16.658	<0.001
Confidence	2.47 (2.19)	2.81 (2.76)	1.90 (1.47)	3.376	0.185

Table 4. Δ between preprocedural and procedural anxiety.

	No distraction group ($n = 32$)	Comic book group ($n = 31$)	VR group ($n = 29$)
Worry	0.22	1.65*	3.76**
Tension	–0.06	1.52*	2.66**
Confidence	0.38	0.65	2.52**

* $p \leq 0.01$, ** $p \leq 0.001$.

Table 5. Pearson correlations between procedural anxiety and pain.

	NRS-11	CHEOPS
Worry	0.70***	0.55***
Tension	0.64***	0.44***
Confidence	0.61***	0.50***

*** $p \leq 0.001$.

4. Discussion

This study investigated the effectiveness of virtual reality as a distraction tool in the management of pain and anxiety during the skin prick test. Several authors note that this procedure causes anxiety and painful discomfort for children [35], although it is considered to be minimally invasive [34]. It is well known in the literature that, when pain is experienced along with anxiety, the subjective perception of that pain increases [11] [12] [13]. This effect was also observed in this study: a positive correlation was observed between the level of anxiety and the perceived and observed pain, supporting the usefulness of using a distraction method during skin prick tests to reduce the resulting discomfort.

The results of this study support the idea that a distraction tool can be effective in reducing pain during skin prick tests. In fact, children in the comic book and VR conditions reported feeling less pain than children who were given no distraction. As for procedural anxiety, children reported feeling less anxiety in the VR condition than in the comic book and no distraction conditions. A significant decrease in procedural compared to preprocedural anxiety was observed only in the two distraction groups (VR and comic book). These results are similar to those reported in the literature concerning the effectiveness of distraction tasks at reducing pediatric pain and anxiety during a medical procedure [17] [18] [22] [32] and more specifically during the skin prick test [37] [38] [39] [40]. No differences were observed between the three groups concerning observer-reported pain levels. This result could be explained by hypothesizing that this age group expresses pain in a non-behavior way, and therefore it is not easily observable. Indeed, the questionnaire used, the CHEOPS, was designed to assess pain in children between 1 and 7 years of age. Although the literature indicates that this scale is also used in older children, it may be less sensitive for the assessment of pain in this age group. Furthermore, several authors report that adults' assessments of pain in children are commonly underestimated in comparison with self-reports, regardless of the scale used [53] [54] [55].

When comparing the groups with each other, a greater reduction in the level of pain and anxiety was observed in the VR group than in the comic book group. This increased effect might be explained by the greater distraction potential of the VR tool. A possible explanation could be based on Wickens' theory of multiple resources [56], which postulates that the attentional resources of different sensory systems operate independently. If that is so, multisensory distractions would presumably consume more resources. The multimodal nature of VR would give it greater potential for distraction. Indeed, the VE used in this study involved the visual and auditory systems but also allowed children to interact actively with the environment.

Using a technology such as VR means that two key concepts are relevant: sense of presence and "cybersickness." The potential to induce a powerful distracting effect by immersion in VR is thought to be related to the sense of presence [57], which is defined as the subjective sense of "being there" in the

virtual environment [58] [59]. The results of a systematic review showed that a high level of presence appears to be associated with more analgesic effects [57]. Cybersickness is a side effect induced by immersion in VR, which could be related either directly to the equipment or to conflicting sensory information [60]. Cybersickness corresponds to symptoms similar to those of motion sickness. This discomfort is said to result from conflicts between three sensory systems: visual, vestibular and proprioceptive [61]. In this study, children reported a satisfying sense of presence in the VR environment and no cybersickness. These findings clearly suggest that VR provides a healthy, efficient distraction from pain and that it has a place in the management of routine aversive procedures, such as the skin prick test. In addition to its usefulness, it has other advantages: financial and time savings, and increased participant motivation due to the attraction of the new technology.

Although this study produced some interesting results, it is affected by certain limitations. First, because our sample size is limited, the results should be replicated with a larger sample to support our conclusions. Second, only subjective perceptions of pain and anxiety were reported, via standard VAS. In future research, these subjective measurements could be supplemented by certain physiological measurements in order to obtain a multimodal assessment of pain perception. Third, this study did not assess the efficacy of VR in the management of pain and anxiety during skin prick tests in younger children (4 to 6 years old). However, this is the age group that feels the most stress and therefore subjective pain [29] [35]. Whether VR can be used effectively as a distraction tool during skin prick testing for younger children requires further study. Finally, no information was collected from nursing staff concerning the advantages and/or disadvantages of the use of VR in their practice. Future investigations should integrate such an evaluation in order to better understand the ergonomic aspects of the tool.

Although the usefulness of VR in pediatrics is emerging, future investigations are needed to better understand the conditions for its application. Further studies should focus on possible moderating factors of VR's efficacy, such as anxiety sensitivity and temperament [22] [37], or the most efficient VR scenarios based on age and gender [62] [63] [64]. Indeed, a better understanding of the processes underlying VR's application for managing pain and anxiety is needed to guide the design of successful VR interventions [62].

5. Conclusion

In conclusion, this study has demonstrated that it is both feasible and useful to apply VR to reduce pain and anxiety in specific pediatric medical procedures, such as the skin prick test, in children aged between 7 and 17 years. The use of this type of tool seems valuable during the skin prick test, which causes anxiety and discomfort in children, even though it is considered to be minimally invasive. The more positive experience of the skin prick test in association with a

virtual reality distraction could facilitate future prick tests and/or other medical investigations.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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