**Interactive video games to improve paediatric procedural pain and anxiety: a systematic review and meta-analysis**

**Running title**: Video games for paediatric pain and anxiety

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**ABSTRACT**

**Background**: Procedural pain and anxiety in children can be poorly controlled, leading to significant short and long-term sequelae such as longer procedure times or future healthcare avoidance. Caregiver anxiety can exacerbate these effects. We aimed to evaluate the effect of interactive video game interventions on children’s procedural pain and anxiety, including the effect of different types of video games on those outcomes. **Methods**: We conducted a systematic review and meta-analysis of the effectiveness of interactive video games compared to standard care in children (0-18 years) undergoing painful procedures. We searched the databases MEDLINE, Embase and PsycInfo. We conducted random-effects meta-analysis using ‘R’ of children’s procedural pain and anxiety, and caregivers’ anxiety. **Results**: Of 2,185 studies screened, 36 were eligible (n=3,406 patients). Studies commonly involved venous access (33%) or day surgery (31%). Thirty-four studies were eligible for meta-analyses. Interactive video games appear to reduce children’s procedural pain (standardised mean difference = -0.43, 95% CI -0.67, -0.20) and anxiety (SMD = 0.61, 95% CI -0.88, -0.34), and caregivers’ procedural anxiety (SMD = -0.31, 95% CI -0.58, -0.04). We observed no difference between preparatory and distracting games, or between virtual reality and non-virtual reality games. We also observed no difference between interactive video games compared to standard care for most medical outcomes (e.g. procedure length), except a reduced need for restraint. Studies reported minimal adverse effects and typically had high intervention acceptability and satisfaction. **Conclusions**: Our findings support introducing easily available video games such as distraction-based conventional video games into routine practice, to minimise paediatric procedural pain and child/caregiver anxiety.

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**Key words:** anxiety, burns, child, pain, perioperative, venepuncture, video game, virtual reality

**INTRODUCTION**

Painful medical procedures are often an inevitable part of paediatric medical care1. Paediatric patients can experience significant anxiety and distress from such procedures2-4, likely exacerbated by anxiety cues from parents5, the unknown hospital environment or staff, and separation from their parents6. Procedural pain and anxiety are often not optimally controlled7, which can cause children to experience agitation8, decreased procedural cooperation8, increased postoperative emergence delirium8, 9, slower postoperative recovery8, 9, and sleep disturbances9 compared to reduced procedural pain and anxiety. Subsequent procedural encounters can involve greater perception of pain and more significant physiological and behavioural reactions10, including in the context of needle phobia, when heightened fear regarding exposure to needles results in significant avoidance behaviour11. In the long-term, this fear and associated distrust of healthcare workers has been associated with treatment avoidance (in the face of compelling need)9-11, poor compliance9, 10 and increased inpatient admission9. These poor health behaviours can lead to social and economic consequences, if participation in work and social activities such as travel and relationships are affected11.

Both pharmacological and non-pharmacological approaches have been trialed to reduce procedural pain and anxiety. Pharmacological methods such as analgesics, anxiolytics and sedatives may be impractical for small or urgent procedures7 and are associated with side effects such as disinhibition, airway obstruction and respiratory depression, postoperative behavioural changes, prolonged recovery time, operating list delays and delayed discharge12, 13. Non-pharmacological interventions such as play therapy and Child Life Specialist therapy involves “promoting effective coping through play, preparation, education and self-expression activities”14. Therapists may improve anxiety and distress in children through distraction from threatening stimuli15. Play and Child Life Therapists may also engage in preparatory play interventions, which help children to better understand the hospital environment and upcoming procedure and may alleviate or prevent anxious cognitions16. Preparatory education is often also targeted to parents, as they are integral to their children’s care17 and adequate procedural information can help to mitigate feelings of distress and helplessness for caregivers during their child’s procedure18. However, some studies have shown that preparatory education may actually increase younger children’s anxiety19, 20. In addition, non-pharmacological interventions such as play and Child Life Specialist therapy can have limited availability due to their time- and resource-intensiveness, as ongoing staff involvement can be costly15. Despite the potential financial benefits from reducing need for anaesthesia or analgesia14, settings with limited resources may not be able to fund programs with sufficient staffing, particularly across multiple departments or out of hours21, 22.

Video games are a promising intervention that may be used either to distract children from pain or to educate and familiarise children in preparation for upcoming procedures8, 12. Engagement with video games is becoming increasingly ubiquitous amongst children23, and children have been shown to prefer computer-assisted learning to other teaching strategies in some instances19. The provision of video games, particularly existing freely available games, may also be less resource-intensive for the healthcare system to run15 than play therapies requiring staff involvement. However, despite the prevalence of digital screens in many healthcare settings, they are not consistently used for pain or anxiety management7.

Research has showed that screen-based technologies can improve procedural pain and/or anxiety relating to burns dressings24 and surgery4, 12. However, the range of screen-based technologies vary widely in terms of cost and effort, as well as the level of user engagement involved. Screen-based activities such as watching videos are passively-engaging, while interactive activities such as video games that require user input for gameplay are actively-engaging and thus may result in greater user immersion. Theoretically, the more attention invested in the intervention, the less available for pain perception, which could lead to a greater reduction in pain25. Decreased anxiety may also result from greater feelings of recreation or escape with greater immersion, decreasing arousal26. Thus, there is a need to investigate whether the theoretical benefit of actively-engaging interventions on procedural pain and anxiety is substantiated in the clinical context.

In addition, it is unclear whether interventions that incorporate preparatory educational information about the upcoming procedure (herein referred to as “preparatory” interventions) may confer an advantage over interventions that only aim to reduce pain and anxiety through distraction7, or whether different types of video games, such as virtual reality (VR) games with an interactive component compared to conventional video games, are more effective. For the purposes of this study we have included all screen-based games with an audiovisual component that responds to user input to change the audiovisual output, and henceforth referred to these as ‘interactive video games’, to cover the range of terms applied to these games. In our study, we therefore aimed to:

1. Evaluate the effect of interactive video game interventions on procedural pain and anxiety in children, compared to standard care or other non-interactive video game interventions, through a meta-analysis of available data, and
2. Compare the effect of different types of interactive video games on child procedural pain and anxiety. These were to include all games aiming to prepare and/or distract children, and games across VR, conventional video game and interactive audiovisual game modalities.

Our secondary aims were to:

1. Evaluate the effect of interactive video game interventions on caregiver anxiety, and
2. Characterise the impact of interactive video game interventions on other aspects of the child and caregiver experience, such as medical outcomes, adverse events and acceptability of the intervention.

**METHODS**

We conducted this systematic review and meta-analyses in accordance with the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines 27. The review protocol is registered with the International Prospective Register of Systematic Reviews (PROSPERO; Registration Number: CRD42019143349).

**Eligibility criteria**

*Studies*

We included published articles that used experimental methods to evaluate the impact of an intervention. We excluded study protocols, studies describing intervention development without evaluation, case studies, reviews, and conference abstracts. We also excluded non-English studies and those published before January 2000, as the rate of technological development has likely rendered older interventions out-of-date or inaccessible.

*Participants*

We included original studies which reported on children and adolescents (0-18 years) who had undergone a painful procedure. We included procedures of any physical medical intervention that could result in pain and could therefore induce anxiety and fear including surgical procedures, dental procedures, needle-based procedures, or wound care. We excluded studies which included adult patients undergoing medical procedures (over 18 years old) and studies published in a language other than English.

*Interventions*

As per the Oxford English Dictionary, we defined ‘video game’ interventions as ‘a game played by electronically manipulating images produced by a computer program on a monitor or other display’28, that is interventions with an audiovisual component which responded to user input. These interventions could be used for preparatory or distraction purposes and included VR video games, customised ‘serious’ games and handheld device-based games. All such games are referred to as ‘interactive video games’ in this paper.

*Comparison groups*

We included studies where a comparison group received either standard care or a different non-interactive and/or non-audiovisual intervention aimed at improving procedural anxiety or pain such as play therapy or anxiolytic medication.

*Outcomes*

To be eligible for inclusion, studies needed to examine procedural anxiety and/or pain as an outcome. Primary outcomes include self-reported, nurse-reported, or caregiver-reported measures of anxiety, pain or distress and physiological parameters reflecting arousal. Secondary outcomes included caregiver anxiety, medical outcomes (such as length of treatment or stay, medication usage, emergence delirium, healing, procedure success rate, procedure cooperation, and long-term stress symptoms or behavioural change), adverse events and the acceptability of the intervention.

**Search strategy (Table 1)**

We conducted electronic searches in three databases: Medline, EMBASE and PsycINFO, from inception of the database up-to and including 26th of June 2020. Our search strategy included keyword and controlled language (e.g. MeSH terms) for the concepts paediatrics, procedural anxiety and pain, and interactive video intervention. We also conducted a manual citation search of review article reference lists and Google Scholar.

**Data collection and analysis**

*Study selection*

We combined the three database search results and removed any duplicate articles. Two investigators (MS, CS or NABY) independently screened the abstracts captured by the search strategy using a checklist based on adherence to the inclusion criteria. Discrepancies between investigator decisions resulted in full text analysis of the discrepant articles, before investigator discussion on eligibility resulting in inclusion or exclusion.

*Data extraction*

For the review, one investigator (MS) extracted data from eligible articles using a standardised data extraction tool that included information about study population (e.g. age and sex), type of procedure, type of intervention, outcome measures, and general conclusions (see Table 2). To assess inter-rater reliability, 25% of articles underwent data extraction by an additional investigator (CS). Both investigators discussed any discrepancies before a consensus was achieved on the appropriate way to report the data. For the meta-analysis, two reviewers (MW, MS or NABY) extracted the following outcome measures: baseline and post-intervention means, standard deviations, mean difference, t-value, p-value and confidence interval, along with other important information such as the number, rate and reason for drop-outs. Discrepancies between extractors were resolved via discussion. We made two attempts per study to obtain missing data from the corresponding author of respective studies, waiting two weeks after each attempt before considering it failed if there had been no response. For paediatric anxiety/pain, we extracted data according to the following hierarchy: self-reported, nurse-reported, caregiver-reported, or physiological surrogate.

*Study quality*

Two investigators (MS, CS or NABY) independently assessed all eligible articles for study quality using the modified Downs and Black checklist. The original checklist is a 27 item tool that facilitates assessment of confounding, selection bias, power, external validity and quality of reporting, with a maximum score of 3229. Item 27, which assesses study power and was scored 0-5 in the original iteration of the checklist, has been modified in line with other recent studies that have used this tool30-34 with 1 point awarded if the article included a power and/or sample size calculation, and 0 if neither of these calculations were reported. Thus the modified tool results in a maximum score of 2830. Based on the modified Downs and Black score, studies were rated as excellent (26-28 points), good (20-25 points), fair (15-19 points) or poor (14 points or less)32, 34.

*Data synthesis*

We conducted random-effects meta-analysis using the *metafor35* package in R36 with the restricted maximum likelihood (REML) estimator for heterogeneity. Due to the different measurement tools used to assess each outcome, we calculated summary effects as the standardised mean difference corrected for small sample size (Hedges’ *g*) with 95% confidence intervals, and considered results statistically significant when the 95% confidence interval did not cross zero. We classified effect sizes as negligible (<0.2), small (<0.5), moderate (<0.8) or large (>0.8) as per Cohen’s classification37. We quantified study heterogeneity using *Q* and *tau2* statistics, and quantified inconsistency using *I2* statistics. We illustrated potential for publication bias using funnel plots and, if >10 studies were available for an outcome, Egger’s regression test (*p*<0.10).

We conducted subgroup analyses of type of interactive videogame (preparatory or distraction-based) and use of VR (yes or no). We also conducted a sensitivity analysis excluding studies rated as ‘poor’ quality. Of the secondary outcomes, we assessed caregiver anxiety in the meta-analysis as we expected more studies to include this outcome, and undertook descriptive analysis of medical outcomes, adverse effects, and acceptability.

**RESULTS**

**Study selection (Figure 1)**

We screened 2185 abstracts and identified 82 studies as requiring full article review. Of those, 51 were excluded. An additional five studies were identified through citation search, resulting in 36 studies fulfilling the inclusion criteria for the systematic review. Thirty-four of those studies were appropriate for meta-analysis, excluding two studies that were not randomised controlled trials (RCTs).

**Study characteristics and quality (Table 2)**

The included 36 studies for the systematic review represented 3406 patients aged between 1-18 years old. Most studies were randomised controlled trials (92%). Studies reported on a range of procedures, most commonly venous access (33%) and day surgery (31%). Studies were most commonly from the USA (22%) and Australia (19%). Studies evaluated VR games (47%), conventional video games (28%) or non-VR customised games (28%). Most studies evaluated distraction games (83%) and the remainder were preparatory. A range of devices were used, most commonly VR headsets (36%) and tablets (17%). In terms of quality assessment, the range of scores was 13-22, with most studies scoring ‘good’ (69%) or ‘fair’ (22%). Two studies scored ‘poor’. Pain was mostly commonly self-reported using the Wong Baker FACES Scale measure38, Faces Pain Scale Revised measure39 or with a Visual Analogue Scale measure. Anxiety was most commonly self-reported with a Visual Analog Scale measure or observer-reported with the modified Yale Preoperative Anxiety Scale measure40. Table 2 presents a summary of results from each of the included studies.

**Intervention effects on paediatric procedural anxiety and pain**

Data for paediatric anxiety was available in 25 intervention groups with 2145 participants (Figure 2). Three studies with this outcome did not provide data suitable for meta-analysis. Overall, children who were playing interactive video games reported less anxiety compared with controls, with a statistically significant and moderate effect size (*g* = -0.61 (95% CI -0.88, -0.34. Substantial heterogeneity and inconsistency were observed (Q = 180.77, *I2* = 89%, *p*<0.001) and Egger’s regression test indicated significant publication asymmetry (z = -2.80, *p*<0.01), illustrated in the funnel plot (Supplementary Figure 1). In our subgroup analysis, we observed no substantial differences between the sub-groups of preparatory/distracting (Figure 2) or VR/non-VR (Supplementary Figure 2).

Data for paediatric pain was available in 25 intervention groups with 1701 participants (Figure 3). Three studies with this outcome did not provide data suitable for meta-analysis. Overall, children who were playing interactive video games reported less pain than children receiving controls, with a statistically significant and small effect size (*g* = -0.43 (95% CI -0.67, -0.20). Substantial heterogeneity and inconsistency were again observed (Q = 116.13, *I2* = 81%, *p*<0.001), while Egger’s regression test did not indicate publication asymmetry (z = -1.66, *p*=0.11), which is illustrated in the funnel plot (Supplementary Figure 5). In our subgroup analysis, we observed no substantial differences between the sub-groups of preparatory/distracting games (Figure 3) or VR/non-VR (Supplementary Figure 6).

**Sensitivity analysis**

We conducted the sensitivity analysis by excluding poor-quality studies. Only one study that had been included in the meta-analysis, Patel et al (2006), was judged as poor quality. This study had contributed data towards the paediatric anxiety outcome, and removing this data had minimal effect on our results (Supplementary Figures 3, 4).

**Intervention effects on secondary outcomes**

*Caregiver anxiety*

Data for caregiver anxiety was available in 6 intervention groups with 491 caregiver participants (Figure 4). One study with two intervention groups did not provide data suitable for meta-analysis for this outcome. Overall, caregivers whose child used an interactive video game reported a statistically significant and small reduction in anxiety, relative to controls (*g* = -0.31 (95% CI -0.58, -0.04). There was no evidence for heterogeneity or inconsistency (Q = 8.71, *I2* = 46%, *p*=0.12) and we did not perform Egger’s regression due to the limited number of studies (Supplementary Figure 7). In our subgroup analysis, the subgroup effects for both preparatory (*g* = -0.35 (95% CI -0.72, 0.02) and distracting (*g* = -0.30 (95% CI -0.80, 0.21) interventions were not significant (Figure 4). The non-VR subgroup effect remained significant (*g* = -0.42 (95% CI -0.69, -0.14) and the VR subgroup comprised of only one study (Supplementary Figure 8).

*Other medical outcomes*

One RCT assessing use of restraint during venepuncture showed a decreased need for restraint41 when a child used an interactive video game compared to standard care. Evidence from the included studies did not suggest a significant effect of interactive games on the following outcomes: anaesthetic induction time (n=1 RCT)42, length of surgery (n=1/1 RCT)43, postoperative length of stay (n=2/2 RCTs)42, 43, postoperative behavioural change (n=3/3 RCTs)26, 44, 45, analgesia usage (n=3/3 RCTs)43, 46, 47, time taken for venepuncture (n=3/3 RCTs)41, 48, 49, number of venepuncture attempts/first venepuncture success rate (n=3/3 RCTs)41, 50, 51 or need for sedation during venepuncture (n=1/1 RCT)41. There was mixed evidence on whether the use of interactive video games was associated with children’s improved burns wound healing (n=1/2 RCTs found an improvement, the other found no difference between groups)46, 52, perioperative procedural compliance (n = 2/3 RCTs found an improvement, the other found no difference between groups)45, 53, 54, anaesthetic emergence delirium (n = 2/3 RCTs found no difference between groups, the other found interactive video games improved emergence delirium)43, 47, 53 or length of burns treatment procedure (n = 4/6 RCTs found no difference between groups, the other two found reduced time of treatment procedure)46, 52, 55-58.

*Adverse events of using interactive video games*

Studies that examined adverse events most commonly included nausea, vomiting and/or motion sickness within their definition of adverse events (n=9/10 RCTs)41, 48, 49, 54, 56, 58-61, with the remaining RCT not providing a definition51. Dizziness, headache, seizures, and claustrophobia were other less commonly monitored outcomes also included (n=3/9 RCTs)41, 49, 54. Most studies reported that zero adverse events occurred (n=6/10 RCTs)48, 51, 54, 56, 58, 61. In the studies that did report the occurrence of adverse events, the absolute numbers of events were described as small (0-4 patients per study arm) and there was no difference observed between intervention and control groups in the number of adverse events reported (n=4/9 RCTs)41, 49, 59, 60.

*Acceptability*

Eighteen studies assessed the acceptability of interactive video games in children, their caregivers and healthcare practitioners (HCPs)5, 15, 26, 41-73. Studies used a range of measures including patterns of engagement with the intervention and customised questionnaires assessing satisfaction with care and the intervention. All studies reported that interactive video game interventions were acceptable to children. Studies comparing satisfaction with treatment between intervention and control groups found that the evidence regarding increased satisfaction with treatment among children appeared to be mixed (n=2/4 RCTs found greater satisfaction and the remaining two found no difference between groups)48, 49, 59, 60, as was the evidence regarding increased satisfaction with treatment from caregivers’ perspectives (n=4/6 RCTs found no difference in satisfaction between groups, while one found increased satisfaction in the interactive video game group and the other found reduced satisfaction in the interactive video game group)42, 45, 52, 59, 64, 70. Studies comparing satisfaction with treatment between intervention and control groups found greater satisfaction from HCPs perspectives in the interactive video game groups (n=2/2 RCTs)60, 70.,

**DISCUSSION**

The results of our review and meta-analysis suggest that children who used interactive video games may experience less procedural pain and anxiety, with a moderate effect size for paediatric anxiety and a small effect size for paediatric pain and caregiver anxiety. For comparison in similar contexts, hypnosis has been found to reduce paediatric procedural anxiety in oncology patients with a large effect size (d=2.30)74, while preoperative introduction to the anaesthetic mask improved children’s cooperation during anaesthetic induction with a small effect size (RR=1.27)12. However, our findings are limited due to substantial heterogeneity and inconsistency in the analyses, reducing the confidence in these conclusions. We found no difference in the effectiveness of preparatory and distracting games, or between VR and non-VR games, on paediatric pain or anxiety, or on caregiver anxiety. There was no difference found between interactive video games compared to standard care for most medical outcomes, with the exception of improved need for restraint during venepuncture and perioperative procedural compliance. Importantly, studies reported minimal adverse effects for the interventions used. Children, caregivers, and HCPs using the interventions reported high acceptability and satisfaction with treatment across the studies.

Our review findings are similar to other reviews examining similar contexts and interventions. A recent Cochrane review on a range of non-pharmacological measures to assist in the induction of anaesthesia in children (such as by reducing preoperative anxiety) found that video games were more effective than midazolam or standard care in reducing preoperative anxiety in children, based on the results of one study, and suggested further research to consolidate the evidence12. Reviews that have focused only on VR found that children who use it experience less pain, including experimental pain75 and across many procedures25, 75, particularly in burns care24 where it has been most investigated25. Other literature has found that video distraction (encompassing both actively-engaging video games and passively-engaging videos) reduces preoperative anxiety compared to parental presence and medication76 and reduces procedural pain and distress compared to non-digital distraction7. Interactive video games may be more effective than passive distractors, such as parental presence or medication, in improving patient outcomes7.

While effective clinical interventions to reduce pain and anxiety theoretically should incorporate information provision, modeling or coping skills9, we did not find a benefit to using such preparatory games over distraction-based games in our subgroup analysis. Distracting video games are often readily accessible, or can be made so from hospital equipment or the use of parental devices7, and can offer more choice than specially made games targeted at certain demographics (such as age groups or genders), supporting their routine use. The significant time, effort and cost that may be required for the development of preparatory interventions further threatens their feasibility and successful clinical implementation.

Similarly, VR is an emerging field that may be used to alleviate procedural pain and anxiety77, previously demonstrated in other health contexts24, 78. Theoretically, VR may alleviate pain more than conventional video games because they require greater immersion and divert one’s attention from the painful experience79.. However, we did not observe any difference in using VR games over conventional video games on patient outcomes. These findings have important implications for low- and middle-income countries where resources, or access to technology, may limit the successful implementation of preparatory games or VR games.

Our review showed that caregivers experienced less anxiety when using interactive video game interventions compared with standard care. Only six studies eligible for inclusion in our review examined caregiver anxiety, despite evidence that caregiver anxiety heightens a child’s anxiety80, and can contribute to long-term negative psychosocial effects among caregivers, including greater anxiety, fear and guilt18. It would also be valuable for future research to more closely evaluate the mechanisms which might account for reduced caregiver anxiety. Given the responsibility that HCPs have in considering the caregiver experience when clinically addressing paediatric procedural pain and anxiety, future interventions should target caregivers as well.

Paediatric acute pain and anxiety is also associated with negative medical and economic sequelae6, 8-10. Our included studies provided inconclusive evidence for effect of interactive video games on other medical outcomes except showing a reduced need for restraint during venepuncture. Our other medical and economic outcomes were only examined by a few studies each and were not included in our meta-analysis, and so each study may not have been individually adequately powered to find a difference. The impact of interactive video games on improving clinical efficiency in these respects may be important to consider further, given unsustainably rising healthcare costs81.

Importantly, while not always demonstrating increased satisfaction with treatment compared to control, the interventions were consistently acceptable and demonstrated good levels of satisfaction where assessed. Assessing the acceptability of an intervention from the perspective of the populations who will be using it82 is integral to patient-centered care81. High acceptability was also important in improving the external validity of our findings; outside of a research setting, these interventions are likely to still have good engagement and high usage. Only one study found that satisfaction with the information provided during preoperative counselling was lower in the interactive video game group than the control group. This highlights that while distracting interactive video games may alleviate paediatric pain and anxiety, information provision is still important to address caregiver information and support needs. Acceptability in HCPs was only assessed by two studies60, 70, however as an important stakeholder in the implementation and use of any child-focused intervention, HCPs should routinely be included in acceptability assessments in future research.

*Strengths and limitations*

Study results may have been positively biased by lack of blinding within our included studies, as only one study included in our review blinded participants and data collectors to the intervention condition. Many studies were small, likely reflecting underpowered studies, and were heterogeneous in terms of the measures used, intervention type, timing, length and frequency, clinical context, and type of control group. This makes comparison difficult and potentially reduces the validity of our conclusions. As with all reviews, reporting and publication bias in our included studies may have also led to a tendency towards positive outcomes. Although our included articles reflected studies from a variety of countries in Europe, Asia, North America, South America, the Middle East and Australasia, they were all English-language articles, reducing the generalisability of our findings globally. Finally, the rate of progress in gaming technology means that the interventions assessed in older studies may have become obsolete, reflecting less-effective interventions than those offered by current technology.

*Future directions*

Further well-designed studies are required to substantiate our conclusions, particularly regarding the lack of benefit of the more-resource intensive VR and preparatory interactive video game interventions. There were also only a few studies examining each medical outcome. However, these data are integral to support the development and introduction of new interventions into a clinical context. While there is clearly evidence to support the routine use of publicly-available interactive video games, further research into optimal timing of the intervention, for example whether delivered at home or in hospital immediately before the procedure, and the optimal level of staff involvement, would also help guide effective implementation into practice.

*Summary and clinical implications*

Given the prevalence of procedural pain and anxiety and their significant adverse consequences, it is imperative that clinicians incorporate effective measures to mitigate them into routine clinical practice. Overall, there is evidence to suggest that children’s use of interactive video games can improve their procedural pain and anxiety, with minimal adverse effects and high levels of satisfaction and acceptability. Our review indicated there was no greater benefit from using preparatory or VR video games, indicating that the costs and time of purchase and/or development of such games by healthcare systems may not always be justified, particularly in resource-limited settings. However, this evidence is still low-grade, and requires substantiation with further high-quality studies. Distraction-based games are a relatively low-cost intervention (to the healthcare system) and appear to be easily incorporated into the clinical context. This is particularly relevant in resource-limited settings where effective but costly interventions such as Child Life Therapy may be financially impractical, although other low-cost non-technological interventions may still be useful especially when video game technology is not available. Management of children’s pain and anxiety around painful procedures should be multimodal, incorporating a range of pharmacological (when appropriate) and non-pharmacological strategies that must be tailored to the child, their environment and their procedure83, 84. Video games, particularly distracting video games, appear to be an easily integrated and valuable tool in the clinician’s armament.

**Authors’ contributions:** MS: Acquisition of data, analysis of data, interpretation of data, drafting the article, revision of manuscript. LK:Study design, interpretation of data, revision of manuscript. ABYN: Acquisition of data, interpretation of data, analysis of data, drafting the article, revision of manuscript. CEW: Study conception and design, interpretation of data, revision of manuscript. MW: Acquisition of data, interpretation of data, analysis of data, revision of manuscript. JK: Study conception and design, interpretation of data, revision of manuscript. BA: Interpretation of data, revision of manuscript. ASD: Interpretation of data, revision of manuscript. CS: Study conception and design, acquisition of data, interpretation of data, revision of manuscript.

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**Table 1.** Search strategy used for the systematic review and meta-analysis

|  |
| --- |
| **Terms** |
| child\* OR paediatric\* OR paediatric\* |
| surg\* OR operat\* OR preop\* OR periop\* OR procedur\* |
| game\* OR serious game OR video\* OR virtual reality |
| educat\* OR distract\* OR inform\* OR anxi\* OR pain\* |
| **Additional limits** |
| English language |
| Articles from 2000-present |
| **Included databases** |
| Medline |
| EMBASE |
| PsychINFO |

**Table 2.** Summary of studies included in the systematic review and meta-analysis

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **First author, Year, Country – Study type (n)** | **Clinical context Intervention** (eligible for this review) **Control** | **Age range** (of recruited subjects if available, otherwise as per inclusion criteria)**, proportion male (%)** | **Quality assessment grade** | **Results** (Results are reported compared to the control, differences are reported only if statistically significant, and where available, results adjusted for confounders are reported. Satisfaction and adverse effects are reported for only the intervention group if the control group was not assessed.) |
| Atzori, 2018, Italy – crossover randomised controlled trial (n=15) | Clinical context: venous access  Intervention: virtual reality game ‘SnowWorld’ using virtual reality headset for distraction  Control: usual care | 7-17 years old, 66.7% male | Fair | Pain – reduced in virtual reality group  Satisfaction – high acceptability in virtual reality group from children  Adverse events (nausea) – no significant difference between groups |
| Atzori, 2018, Italy – crossover randomised controlled trial (n=5) | Clinical context: dental procedures Intervention: virtual reality game ‘SnowWorld’ using virtual reality goggles for distraction Control: usual care | 11-17 years old, 66% male | Fair | Pain – reduced in virtual reality group Satisfaction – higher fun in virtual reality group compared to control, high satisfaction from healthcare professional with interactive video game Adverse events (nausea) – no significant difference between groups |
| Brown, 2014, Australia – parallel randomised controlled trial (n=75) | Clinical context: burns wound care Intervention: customised video game on customised handheld ‘Ditto’ device for preparation and distraction Control: usual care | 4-12 years old, 61% male | Good | Pain – no significant difference between groups  Anxiety – no significant difference between groups  Wound healing – improved in interactive video game group  Time for procedure – no significant difference between groups  Satisfaction – no significant difference between groups for caregivers |
| Buffel, 2019, The Netherlands – parallel randomised controlled trial (n=20) | Clinical context: day surgery Intervention: customised ‘serious’ video game on computer for preparation Control: usual care | 6-10 years old, 45% male | Good | Pain – no significant difference between groups Anxiety – reduced in interactive video game group Parental anxiety – no significant difference between groups Satisfaction – high in interactive video game group |
| Campbell, 2005, Scotland – parallel randomised controlled trial (n=198) | Clinical context: dental procedures Intervention: customised video game on computer for preparation Control: usual care | 3-10 years old, 57% male | Good | Anxiety – reduced in interactive video game group |
| Caruso, 2019, United States – parallel randomised controlled trial (n=220) | Clinical context: venous access Intervention: virtual reality game (‘Ocean Rift’, ‘Pebbles the Penguin’ or Space Pups’) using virtual reality headset for distraction Control: usual care | 7-18 years old, 57% male | Good | Pain – no significant difference between groups  Anxiety – no significant difference between groups  Induction compliance – no significant difference between groups Adverse events (nausea, vomiting, motion sickness, dizziness, seizure) – none in virtual reality group Satisfaction – high in virtual reality group |
| Chan, 2019, Australia – parallel randomised controlled trial (n=252) | Clinical context: venous access in emergency department and venous access in outpatient department Intervention: customised virtual reality game using virtual reality headset for distraction Control: usual care | 4-11 years old, 54% male in emergency department study, 57% male in outpatient department study | Good | Pain – no significant difference between groups Anxiety – no significant difference between groups Time for procedure – no significant difference between groups Number of attempts – no significant difference between groups Need for sedation – no significant difference between groups Need for restraint – reduced in virtual reality group Adverse effects (dizziness, nausea, vomiting, headache) – no significant difference between groups Satisfaction – high in virtual reality group |
| Chow, 2017, Canada – parallel randomised controlled trial (n=40) | Clinical context: day surgery Intervention: customised video game on tablet for preparation Control: usual care | 7-13 years old, 53% male | Good | Anxiety – reduced in interactive video game group Satisfaction – high acceptability in interactive video game group |
| Crevatin, 2016, Italy – parallel randomised controlled trial (n=200) | Clinical context: venous access Intervention: conventional video game ‘Angry Birds’ on tablet for distraction Control: usual care | 4-13 years old, 49% | Good | Pain – no significant difference between groups Procedural success rate on first attempt – no significant difference between groups Adverse events – no significant difference between groups |
| Cumino, 2017, Brazil – parallel randomised controlled trial (n=84) | Clinical context: day surgery Intervention: conventional video game (choices included ‘Angry Birds’, ‘Talking Tom’) on smart phone for distraction Control: usual care | 4-8 years old, 70% male | Good | Anxiety: reduced in interactive video game group Satisfaction – reduced satisfaction with information provision in interactive video game group |
| Das, 2005, Australia – crossover randomised controlled trial (n=7) | Clinical context: burns wound care Intervention: customised virtual reality game based on ‘Quake’ using head-mounted display and mouse for distraction Control: usual care | 5-16 years old, 67% male | Fair | Pain – reduced in virtual reality group Time for procedure – no significant difference between groups Satisfaction – high acceptability in virtual reality group |
| Dumoulin, 2019, Canada – parallel randomised controlled trial (n=59) | Clinical context: venous access Intervention: customised virtual reality game based on ‘SnowWorld’ using head-mounted display and mouse for distraction Control: usual care | 8-17 years old, 65% male | Good | Anxiety – reduced in virtual reality group Pain – no significant difference between groups Adverse events (cybersickness) – no significant difference between groups  Satisfaction – no significant difference between groups |
| Dwairej, 2019, Jordan – parallel randomised controlled trial (n=128) | Clinical context: day surgery Intervention: conventional video game (choices included ‘Need for Speed’, ‘Mario’) using handheld device (in addition to mask play) for distraction Control: usual care | 5-11 years old, 45% male | Good | Anxiety – reduced in video game group Induction compliance – improved in interactive video game group Emergence delirium – no significant difference between groups |
| Eijlers, 2019, The Netherlands – parallel randomised controlled trial (n=191) | Clinical context: day surgery Intervention: customised virtual reality game based on operating theatre using head-mounted display and controller for preparation Control: usual care | 4-12 years old, 53% male | Good | Anxiety – no significant difference between groups Pain – no significant difference between groups Parental anxiety – no significant difference between groups Rescue analgesia use – no significant difference between groups Emergence delirium – no significant difference between groups |
| Fernandes, 2015, Portugal – parallel randomised controlled trial (n=90) | Clinical context: day surgery Intervention: one arm customised video game on tablet for preparation; one arm customised video game on tablet for distraction Control: usual care | 8-12 years old, 77% male | Fair | Anxiety – reduced in interactive video game for preparation group, no significant difference between interactive video game for distraction group and control Parental anxiety – reduced in interactive video game for preparation group, no significant difference between interactive video game for distraction group and control |
| Fortier, 2015, United States – parallel randomised controlled trial (n=82) | Clinical context: day surgery Intervention: customised video game on computer for preparation Control: usual care | 2-7 years old, 82% male | Good | Anxiety – reduced in interactive video game group Pain – no significant difference between groups Parental anxiety – reduced in interactive video game group in holding area but not at time of separation Use of analgesia – no significant difference between groups Length of surgery – no significant difference between groups Length of recovery stay – no significant difference between groups Emergence delirium – reduced in interactive video game group Satisfaction – high acceptability in interactive video game group |
| Gold, 2006, United States – parallel randomised controlled trial (n=20) | Clinical context: venepuncture Intervention: virtual reality game ‘Street Luge’ using head-mounted display for distraction Control: usual care | 8-12 years old, 60% male | Good | Pain – no significant difference between groups Anxiety – no significant difference between groups  Adverse events (simulator sickness) – no significant difference between groups Satisfaction – high satisfaction in virtual reality group |
| Hoffman, 2019, United States – crossover randomised controlled trial (n=48) | Clinical context: burns wound care Intervention: virtual reality game ‘SnowWorld’ using virtual reality goggles and mouse for distraction Control: usual care | 6-17 years old, 71% male | Fair | Pain – reduced in virtual reality group |
| Huntington, 2018, England – parallel randomised controlled trial (n=176) | Clinical context: dental procedures Intervention: customised ‘serious’ video game on computer for preparation Control: usual care | 5-7 years old, 49% male | Good | Anxiety – no significant difference between groups Induction time – no significant difference between groups Length of recovery stay – no significant difference between groups Time to discharge – no significant difference between groups Satisfaction – no significant difference between groups |
| Inan, 2019, Turkey – parallel randomised controlled trial (n=180) | Clinical context: venous access Intervention: conventional video game (choices included ‘Flappy Bird’, ‘Minion Rush’) on tablet for distraction Control: usual care | 6-10 years old, 49% male | Good | Anxiety – reduced in interactive video game group Pain – reduced in interactive video game group |
| Jeffs, 2014, United States – parallel randomised controlled trial (n=30) | Clinical context: burns wound care Intervention: virtual reality game ‘SnowWorld’ using virtual reality helmet attached to tripod and trackball for distraction Control: usual care | 10-17 years old, 68% male | Good | Pain – no significant difference between groups |
| Kipping, 2012, Australia – parallel randomised controlled trial (n=41) | Clinical context: burns wound care Intervention: virtual reality game (‘Chicken Little’ for 11 to 13-year-olds, ‘Need for Speed’ for 14 to 17-year-olds) using head-mounted display and joystick for distraction Control: usual care | 11-17 years old, 68% male | Good | Pain – no significant difference between groups Length of procedure – no significant difference between groups Adverse events (nausea) – no significant difference between groups  Satisfaction – moderate ‘presence’ reported in virtual reality group |
| Ko, 2016, United States – parallel randomised controlled trial (n=146) | Clinical context: cast room procedures Intervention: conventional video game on tablet for distraction Control: usual care | 1-18 years old, 58% male | Fair | Anxiety – higher in video game group prior to procedure, no significant difference during or after procedure |
| Marechal, 2017, France – parallel randomised controlled trial (n=115) | Clinical context: day surgery Intervention: conventional video game on tablet for distraction Control: usual care | 4-11 years old, 69% male | Good | Anxiety – no significant difference between groups Satisfaction – higher in video game group |
| Matthyssens, 2020, The Netherlands – parallel randomised controlled trial (n=72) | Clinical context: day surgery Intervention: one arm customised ‘serious’ video game ‘CliniPup’ on computer for preparation; one arm conventional video game on computer for distraction Control: usual care | 5-11 years old, 49% male | Good | Anxiety – reduced in interactive  video game for preparation group, no significant difference between interactive video game for distraction and control groups Parental anxiety – no significant difference between groups Pain – no significant difference between groups Behavioural change – no significant difference between groups |
| Miller, 2010, Australia – parallel randomised controlled trial (n=80) | Clinical context: burns wound care  Intervention: one arm customised video game ‘Bobby got a burn’ for preparation on custom device; one arm video game for distraction on custom device; one arm conventional video game for distraction on commercially available device Control: usual care | 3-10 years old, 59% male | Good | Pain – reduced in interactive video game for preparation or distraction on custom device, no significant difference between interactive video game for distraction on commercially available device and control groups Length of treatment – reduced in interactive video game for preparation or distraction on custom device, no significant difference between interactive video game for distraction on commercially available device and control groups |
| Miller, 2011, Australia – parallel randomised controlled trial (n=40) | Clinical context: burns wound care Intervention: customised video game ‘Bobby got a burn’ on custom device for preparation and distraction  Control: usual care | 3-10 years old, 53% male | Good | Pain – reduced in interactive video game group Wound healing time – no significant difference between groups Time for treatment – reduced in interactive video game group Use of medications – no significant difference between groups Adverse events (nausea, motion sickness) – no significant difference between groups |
| Minute, 2012, Italy – parallel randomised controlled trial (n=97) | Clinical context: venous access Intervention: conventional video game ‘WiiPlay’ on console with remote for distraction Control: usual care | 4-10 years old, 51% male | Good | Pain – no significant difference between groups Number of procedure attempts – no significant difference between groups |
| Mott, 2008, Australia – parallel randomised controlled trial (n=42) | Clinical context: burns wound care Intervention: customised augmented virtual reality game ‘Hospital Harry’ on LCD screen with plastic figures for distraction Control: usual care | 3-14 years old, 71% male | Fair | Pain – reduced in interactive video game group for long dressing time subgroup  Time for treatment – no significant difference between groups |
| Nilsson, 2009, Sweden – non-randomised experiment (n=42) | Clinical context: venous access Intervention: virtual reality game ‘The hunt of the diamonds’ using 3-dimensional display with remote for distraction Control: usual care | 5-18 years old, 60% male | Fair | Pain – no significant difference between groups Satisfaction – high satisfaction in virtual reality group |
| Ozalp, 2020, Turkey – parallel randomised controlled trial (n=136) | Clinical context: venous access Intervention: virtual reality game ‘Ocean Rift’ using virtual reality headset for distraction Control: usual care | 5-12 years old, 54% male | Good | Pain – reduced in virtual reality group Anxiety – reduced in virtual reality group |
| Patel, 2006, United States – parallel randomised controlled trial (n=112) | Clinical context: day surgery Intervention: conventional video game on handheld device for distraction Control: usual care | 4-12 years old, 62% male | Poor | Anxiety – reduced in interactive video game group Behavioural change – no significant difference between groups |
| Piskorz, 2018, Poland – non-randomised experiment (n=38) | Clinical context: venous access Intervention: customised virtual reality Multiple Object Tracking game using head-mounted display for distraction Control: usual care | 7-17 years old, 53% male | Fair | Pain – reduced in virtual reality group Anxiety – reduced in virtual reality group |
| Ryu, 2018, South Korea – parallel randomised controlled trial (n=69) | Clinical context: day surgery Intervention: customised virtual reality game incorporating operating theatre environment using head-mounted display and hand motion controlled for preparation Control: usual care | 4-10 years old, 58% male | Good | Anxiety – lower in virtual reality group Induction compliance – improved in virtual reality group Behavioural change – no significant difference between groups Satisfaction – no significant difference between groups |
| Walther-Larsen, 2019, Denmark – parallel randomised controlled trial (n=64) | Clinical context: venous access Intervention: virtual reality game ‘Seagull Splash’ using virtual reality glasses for distraction Control: usual care | 7-16 years old, 81% male | Good | Pain – no significant difference between groups Time for procedure – no significant difference between groups Adverse events (nausea, vomiting, dizziness, claustrophobia) – no significant difference between groups Satisfaction – no significant difference between groups |
| Wolitzky, 2005, United States – parallel randomised controlled trial (n=20) | Clinical context: venous access Intervention: virtual reality ‘gorilla habitat’ game using head-mounted display and joystick for distraction Control: usual care | 7-14 years old, 60% male | Poor | Pain and anxiety (composite ‘distress’ measure) – no significant difference between groups |

LCD = liquid crystal display

**FIGURE LEGENDS**

**Figure 1:** Flowchart of study selection

**Figure 2:** Paediatric anxiety forest plot - the effect of interactive video games compared to control on paediatric anxiety (bottom) and split by preparatory and distraction-based video games (body)

**Figure 3:** Paediatric pain forest plot - the effect of interactive video games compared to control on paediatric pain (bottom) and split by preparatory and distraction-based video games (body)

**Figure 4:** Caregiver anxietyforest plot - the effect of interactive video games compared to control on paediatric pain (bottom) and split by preparatory and distraction-based video games (body)