Heliyon 10 (2024) e35223

Contents lists available at ScienceDirect

Heliyon

journal homepage: www.cell.com/heliyon

Research article

# Hypnosis and nitrous oxide impact on the school aged patients' anxiety and cooperation candidate for tooth extraction: A randomized clinical trial

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ARTICLE INFO

*Keywords:*
Anxiety
Conscious sedation
Cooperation
Hypnosis
Nitrous oxide
Pediatric dentistry
Tooth extraction

ABSTRACT

*Background:* This randomized clinical trial (RCT) investigated whether hypnosis would lead to favorable outcomes in reducing anxiety, enhancing cooperation, and improving physiological responses in school-aged children undergoing tooth extraction compared to nitrous oxide/oxygen ($N_2O/O_2$) and conventional behavior guidance (CBG).

*Methods:* Sixty-six school-aged children (mean age: 7.87 ± 1.18 years) who needed one posterior primary tooth extraction were included. Children with low-to-moderate anxiety were randomly divided into three groups (n = 22 each): hypnosis, $N_2O/O_2$, and CBG. Anxiety levels during and after anesthetic injection and tooth extraction were assessed using the Venham Clinical Anxiety Scale (VCAS) and the Venham Picture Test (VPT). Changes in heart rate (HR) and oxygen saturation ($SpO_2$) were monitored. Children's cooperation levels were measured using the Venham Clinical Cooperation Scale (VCCS).

*Results:* The VPT scores were significantly higher in the CBG group than in the $N_2O/O_2$ and hypnosis groups ($p < 0.001$). The VCAS scores in the $N_2O/O_2$ group were lower than those in the CBG group ($p < 0.05$) and were comparable to those in the hypnosis group. The VCCS scores were significantly higher in the CBG group than in the $N_2O/O_2$ and hypnosis groups ($p < 0.05$). HR changes in the $N_2O/O_2$ group were significantly lower than in the hypnosis and CBG groups ($p < 0.05$). No significant difference in pain was observed between the groups the day after the intervention.

*Conclusion:* $N_2O/O_2$ inhalation and hypnosis are effective in reducing self-reported and observed anxiety and improving cooperation levels in pediatric patients during dental extraction. Moreover, the frequency of reported pain was lower in the hypnosis group compared to the other groups.

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https://doi.org/10.1016/j.heliyon.2024.e35223
Received 5 March 2024; Received in revised form 15 July 2024; Accepted 24 July 2024
Available online 26 July 2024

## 1. Introduction

Dental anxiety is prevalent, affecting approximately 26 % of schoolchildren worldwide [1]. Procedures such as injections, cavity preparation, and extractions evoke the most intense emotional responses. This anxiety can be managed pharmacologically through conscious sedation or general anesthesia, or non-pharmacologically using techniques like the tell-show-do (TSD) method, distraction, role modeling, and positive reinforcement [2]. While many dental procedures can be performed with non-pharmacological techniques, highly anxious children may require pharmacological interventions, including general anesthesia and conscious sedation with nitrous oxide/oxygen ($N_2O/O_2$) [3].

The Council of European Dentists recommends $N_2O/O_2$ sedation as the standard sedative technique, involving the inhalation of sub-anesthetic and titrated doses of $N_2O$ and $O_2$ [4]. The success rate of $N_2O/O_2$ sedation in pediatric dental patients is reported to be as high as 91.9 % [5]. However, it is a technique-sensitive procedure, relying heavily on the patient's acceptance of the mask and continuous inhalation throughout the procedure, which can be challenging in fearful children [6]. Therefore, alternative techniques need to be investigated as possible substitutes for $N_2O/O_2$ sedation.

Hypnosis has gained popularity in pediatric medicine and dentistry as it is recognized as an effective tool for reducing pain and anxiety across various patient groups [7]. Unlike $N_2O/O_2$ sedation, hypnosis does not require any specific equipment. It is particularly effective with children aged 8 to 12, and even children as young as four respond well [8].

In dental treatments, Sabherwal et al. [9] reported that hypnosis effectively reduced anxiety and pain during dental extractions in children aged 8–12, though their study included only children with anxiety above mild levels and did not consider hypnotizability during patient recruitment. Rienhoff et al. [10] found that using low-dose midazolam and hypnosis during restorative treatments and tooth extractions improved patient behavior and decreased discomfort between sessions. However, their study lacked a control group, making it difficult to isolate the effect of hypnosis alone, and they did not categorize the initial anxiety level of the children. A recent systematic review and meta-analysis by Wolf et al. [11] reported inconsistencies in the literature regarding the efficacy of hypnosis on dental anxiety and highlighted a high level of heterogeneity between studies. Most studies have used subjective and self-reported measures to evaluate the effectiveness of hypnosis [11]. Additionally, Sola et al. [12] found that hypnosis can be a safe alternative to general anesthesia for pediatric superficial surgery. However, no previous study has compared the efficacy of hypnosis with $N_2O/O_2$ sedation.

Therefore, the main objective of the current randomized clinical trial (RCT) is to compare the efficacy of hypnosis with $N_2O/O_2$ sedation and conventional behavior guidance (CBG) in reducing children's anxiety during anesthesia injection and tooth extraction, using several objective and subjective indices. The null hypothesis is that hypnotizing school-aged children will reduce their anxiety and enhance their cooperation, similar to $N_2O/O_2$ sedation or CBG.

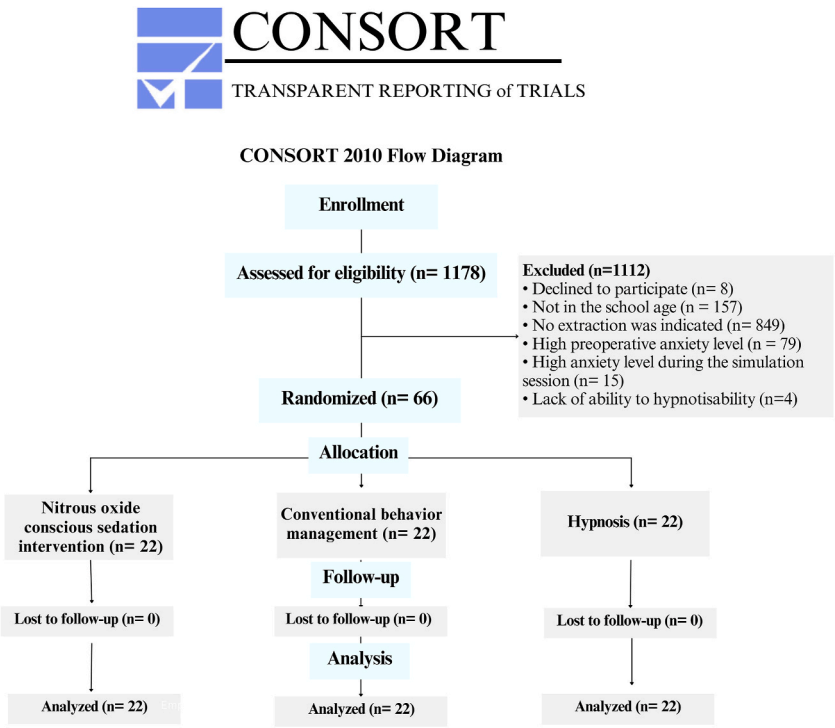


**Fig. 1.** CONSORT flow diagram of study recruitment.

## 2. Materials and methods

The protocol for this RCT was approved by the Ethics Committee of Mashhad University of Medical Sciences (Code: IR.MUMS.DENTISTRY.REC.1397.026) and registered at the Iranian Registry of Clinical Trials (IRCT) (identifier: IRCT20161007030193N3, https://www.irct.ir/trial/35736). The study was reported according to the CONSORT checklist. Fig. 1 shows the flow diagram of the study.

### 2.1. Sample size calculation

The sample size was calculated based on the findings of a previous study [13]. With 12/14 and 5/15 subjects in the hypnosis and control groups, respectively, scoring less than 30 on the Modified Yale Preoperative Anxiety Scale (mYPAS) during anesthesia injection, and considering an $\alpha = 0.05$ and $\beta = 0.2$, a sample size of 13 per group was required. To account for a 30 % dropout rate, the sample size was increased to 22 participants per group to enhance the study's precision.

### 2.2. Participants

A total of 1178 patients were referred to the Pediatric Dentistry Department at Mashhad Dental Faculty for routine dental exams. From these, 66 school-aged children (6.5–10 years old) were selected based on the following inclusion criteria.

- Complete physical and mental health
- At least one primary molar is indicated for extraction without signs of luxation or abscess.
- The tooth root length is at least one-third of its original size in radiographic examinations.
- Previous dental treatment experience without hypnosis or $N_2O/O_2$ sedation
- Mild to moderate dental anxiety, evaluated using specific anxiety indices, as explained below.

Children were excluded if they or their parents refused to cooperate or were unwilling to be separated from their parents during treatment. The study's risks and benefits were clearly explained to the parents, and written informed consent were obtained.

### 2.3. Initial anxiety assessment

The Children's Fear Survey Schedule (CFSS-DS) was used to identify patients with mild to moderate anxiety, with parents providing information. The CFSS-DS has high internal consistency ($\alpha = 0.861$) and includes 15 items related to dental treatment, scored from 1 (not afraid) to 5 (very afraid), with total scores ranging from 15 to 75 [14]. Participants with scores of 16 or higher were selected. The Modified Child Dental Anxiety Scale (faces version) (MCDAS(f)) was also completed for each child, and those scoring between 16 and 26 were included. MCDAS(f) also has high internal consistency (Cronbach's alpha = 0.82) [15].

To assess state anxiety, a simulation involved placing a cotton roll on the candidate's tooth without topical anesthesia and applying finger pressure. The dentist then evaluated the child's reaction using the Venham Clinical Anxiety Scale (VCAS), enrolling those who scored between 1 and 5. The hypnotizability of each participant was assessed by the team's hypnotist (M.F)

### 2.4. Randomization and participants' allocation

Participants were randomly assigned through block randomization, considering gender and anxiety levels (low and moderate). They were allocated into four blocks: girl with low anxiety, girl with high anxiety, boy with low anxiety, and boy with high anxiety. Within each block, participants were assigned to one of three interventions.

- *Conventional Behavior Guidance (CBG):* This approach used behavioral techniques tailored to the child's anxiety type. Strategies included verbal and non-verbal communication, such as TSD method, positive reinforcement, and distraction.
- *Hypnosis:* This technique involved eye fixation and verbal suggestions. During hypnotic induction, the hypnotist gently guided patients through calming, relaxing, or enjoyable imagery to help them feel more at ease, distract them from unpleasant stimuli, and make them more receptive to therapeutic suggestions. The deepening phase included nature imagery or storytelling, and analgesia was induced with specific conditioning over 24 h before releasing the patient from hypnosis
- *Nitrous Oxide Sedation:* This method used a $N_2O/O_2$ gas mixture for rapid induction. After 10 min of inhaling 100 % oxygen, the $N_2O$ and $O_2$ levels were adjusted to 50 %, inducing mild muscle relaxation and drooping eyelids. Following the anesthetic injection, the concentration was reduced to 30 %, then increased back to 50 % for tooth extraction. After the procedure, the child inhaled pure $O_2$ for 10 min and was discharged with parental assistance if they met the criteria.

### 2.5. Blinding

Blinding was not feasible due to the visible nasal mask for $N_2O/O_2$ treatment and the presence of the hypnotist for the hypnosis group.

### 2.6. Clinical procedure

All treatments were performed in the sedation room of the Pediatric Dentistry Clinic at Mashhad University of Medical Sciences, Faculty of Dentistry. Parents were not allowed in the operating room. Lidocaine 2 % with adrenaline 1:80,000 was used for injections. Tooth extraction was performed with an elevator and forceps after ensuring anesthesia. One pediatric dentistry specialist (A.M) conducted all treatments.

### 2.7. Assessment of anxiety and cooperation

Dental treatments were video-recorded for evaluation. Two independent observers (I.P, F.M) reviewed the footage to assess children's anxiety and cooperation during local anesthesia administration and tooth extraction using the VCAS and Venham Clinical Cooperation Scale (VCCS). Both scales have 6 behavioral levels, from 0 to 5, with the highest score indicating the highest anxiety and lowest cooperation and favorable Cronbach's alpha values (0.934 and 0.90 for VCAS and VCCS, respectively) [16]. Discrepancies were resolved by joint review and consensus. Post-treatment, the Venham Picture Test (VPT) was used as a self-report anxiety scale, with scores ranging from 0 (least anxious) to 8 (most anxious) and high internal consistency (Cronbach's alpha = 0.60) [17].

### 2.8. Physiological monitoring

Oxygen saturation ($SpO_2$) and heart rate (HR) were monitored with a pulse oximeter attached to the left index finger every minute before, during, and after treatment. $SpO_2$ monitoring was especially important during $N_2O/O_2$ inhalation [18]. Pain levels were assessed through follow-up phone calls the next day.

### 2.9. Statistical analysis

Data were analyzed using SPSS 20.0 (IBM Inc., New York, USA). The Kolmogorov–Smirnov test checked for normal distribution. CFSS-DS and MCDAS(f) scores, HR, and $SpO_2$ were compared using ANOVA and Tukey's post-hoc test. Baseline physiological variables were compared with post-intervention values using a paired samples *t*-test. VPT, VCAS, and VCCS scores were compared using the Kruskal–Wallis test. The Chi-squared test analyzed gender, jaw distribution, and post-treatment pain. Correlations between variables were evaluated using the Spearman coefficient, with significance set at 0.05.

## 3. Results

Participants' mean age was 7.87 ± 1.18 years (range: 6–10.5 years), with girls comprising half of the sample. The intervention groups were well-matched in terms of gender, age, and whether upper or lower molars were treated (Table 1).

### 3.1. Initial anxiety assessment

The primary anxiety level was measured using the CFSS-DS index, with scores of 37.77 ± 5.53 for the $N_2O/O_2$ group, 36.77 ± 6.69 for the hypnosis group, and 37.23 ± 5.70 for the CBG group (p = 0.858). The MCDASf scale also indicated comparable initial anxiety levels across the groups ($N_2O/O_2$ = 19.77 ± 2.52; hypnosis = 19.50 ± 2.42; CBG = 20.50 ± 2.55; p = 0.379).

### 3.2. Patient's anxiety and cooperation during injection and tooth extraction

The participants' VPT, VCAS, and VCCS scores are presented in Table 2. The VPT index was significantly higher in the CBG group (4.36 ± 2.46) compared to the $N_2O/O_2$ and hypnosis groups (1.18 ± 1.84 and 0.95 ± 1.43, respectively; p < 0.001).

The VCAS scores were similar between the $N_2O/O_2$ and hypnosis groups but significantly lower than those in the CBG group during injection (0.45 ± 0.73 vs. 1.73 ± 1.60; p = 0.007) and extraction (0.77 ± 0.86 vs. 1.68 ± 1.39; p = 0.037). Although the VCAS scores in the hypnosis group were lower than those in the CBG group, the difference was not statistically significant.

The VCCS scores during injection and extraction were significantly higher in the CBG group (1.27 ± 1.20 and 1.50 ± 1.43, respectively) compared to the $N_2O/O_2$ (0.27 ± 0.45; p = 0.002 and 0.50 ± 0.74; p = 0.014, respectively) and hypnosis groups (0.50 ± 0.67; p = 0.040 and 0.50 ± 0.673; p = 0.019, respectively).

**Table 1**
Participants' demographic findings.

| Variables | | $N_2O/O_2$ | Hypnosis | CGB | Total | P value |
|---|---|---|---|---|---|---|
| Mean age | | 7.51 ± 1.03 years | 7.9 ± 1.1 years | 8.16 ± 1.33 years | 7.87 ± 1.18 | 0.354 |
| Gender | Girls | 12 (54.5 %) | 9 (40.9 %) | 12 (54.5 %) | 33 (50.0 %) | 0.580 |
| | Boys | 10 (45.5 %) | 13 (59.1&) | 10 (45.5 %) | 33 (50.0 %) | |
| Jaw | Upper jaw | 5 (22.7 %) | 3 (13.6 %) | 5 (22.7 %) | 13 (19.69 %) | 0.793 |
| | Lower jaw | 17 (77.3 %) | 19 (86.4 %) | 17 (77.3 %) | 53 (80.30 %) | |

**Table 2**
Mean ranks of children' anxiety and cooperation scores during the dental procedures in the studied groups.

| Variable (Scale) | Intervention | $N_2O/O_2$ | Hypnosis | CBG | P value |
|---|---|---|---|---|---|
| Self-reported Anxiety (VPT) | Injection and extraction | 1.18 ± 1.84 a | 0.95 ± 1.43 a | 4.36 ± 2.46 b | <0.001* |
| Anxiety (VCAS) | Injection | 0.45 ± 0.73 a | 0.73 ± 0.76 ab | 1.73 ± 1.60 b | 0.009* |
| | Extraction | 0.77 ± 0.86 a | 0.82 ± 0.795 ab | 1.68 ± 1.39 b | 0.023* |
| Cooperation (VCCS) | Injection | 0.27 ± 0.45 a | 0.50 ± 0.67 a | 1.27 ± 1.20 b | 0.002* |
| | Extraction | 0.50 ± 0.74 a | 0.50 ± 0.67 a | 1.50 ± 1.43 b | 0.006* |

*Values less than 0.05 represent a significant difference between the groups according to the Kruskal Wallis test.
In each row, different lower-case letters represent the result of the pairwise comparison between the groups according to the post-hoc with Bonferroni correction test ($p < 0.05$).
Values less than 0.05 represent a significant difference between the groups according to the Kruskal Wallis test.

Half of the children in the $N_2O/O_2$ group reported zero anxiety during the procedure. Similarly, half of the participants in the hypnosis group reported zero or mild anxiety. None of the participants in the $N_2O/O_2$ and hypnosis groups reported severe anxiety. In contrast, 25 % of children in the CBG group experienced moderate to severe anxiety during injection (VCAS scores ≥3).

### 3.3. Physiological parameters

The physiological parameters (heart rate and oxygen saturation level) and their changes during the treatment are illustrated in Table 3. In the $N_2O/O_2$ group, participants' HR remained comparable to baseline values; however, it increased significantly in the hypnosis (injection: $p = 0.001$; extraction: $p < 0.001$) and CBG groups (injection: $p = 0.002$; extraction: $p = 0.001$). In contrast, $SpO_2$ levels in the $N_2O/O_2$ group increased significantly after injection ($p = 0.009$) and extraction ($p = 0.013$).

Baseline values of physiological parameters were similar among the groups. However, post-injection, HR was significantly higher in the CBG group compared to the $N_2O/O_2$ ($p < 0.001$) and hypnosis groups ($p = 0.035$). Additionally, HR in the hypnosis group was significantly higher than in the $N_2O/O_2$ group ($p = 0.006$). Post-extraction, HR in the $N_2O/O_2$ group was significantly higher than in the CBG ($p < 0.001$) and hypnosis groups ($p = 0.019$). After both injection and extraction, $SpO_2$ values were higher in the $N_2O/O_2$ group compared to the hypnosis ($p < 0.001$) and CBG groups ($p < 0.001$).

While $SpO_2$ changes were similar across groups, HR changes varied significantly (ANOVA, $p < 0.001$). Tukey's post-hoc test showed HR changes during injection (−3.05 ± 13.07) and extraction (+0.65 ± 12.17) were significantly lower in the $N_2O/O_2$ group compared to the hypnosis (+11.28 ± 13.48; $p = 0.001$ and + 13.39±13.48; $p = 0.002$, respectively) and CBG groups (+10.66 ± 11.61; $p = 0.001$ and + 11.68±12.47; $p = 0.015$, respectively).

### 3.4. Presence of pain after 24 h

As shown in Table 4, 72 % of patients in the hypnosis group reported no pain after 24 h. However, the Chi-square test indicated no significant difference between the groups.

**Table 3**
Mean ± standard deviation of the physiological parameters (heart rate and oxygen saturation level) and their changes during the treatment time.

| Variables | Groups | Physiological parameters | | | | | Mean changes in physiological parameters | |
|---|---|---|---|---|---|---|---|---|
| | | Baseline | After injection | P value | After Extraction | P value | During injection | During extraction |
| Heart rate | $N_2O/O_2$ | 98.54 ± 16.35 | 95.49 ± 14.23 a | 0.286 | 99.20 ± 14.46 a | 0.802 | −3.05 ± 13.07 a | +0.65 ± 12.17 a |
| | Hypnosis | 98.98 ± 14.01 | 110.26 ± 12.79 b | 0.001# | 112.38 ± 12.41 b | <0.001# | +11.28 ± 13.48 b | +13.39 ± 13.48 b |
| | CBG | 109.42 ± 18.98 | 121.95 ± 18.10 c | 0.002# | 122.97 ± 19.38 b | 0.001# | +10.66 ± 11.61 b | +11.68 ± 12.47 b |
| P value | | 0.064 | <0.001* | | <0.001* | | <0.001* | <0.001* |
| Oxygen saturation | $N_2O/O_2$ | 98.11 ± 0.75 | 98.85 ± 0.87 a | 0.009# | 98.84 ± 0.79 | 0.013# | +0.65 ± 1.12 | +0.64 ± 1.11 |
| | Hypnosis | 97.51 ± 0.88 | 97.72 ± 0.81 b | 0.243 | 97.65 ± 0.59 | 0.433 | +0.20 ± 0.80 | +0.14 ± 0.84 |
| | CBG | 97.76 ± 0.89 | 97.88 ± 0.79 b | 0.395 | 97.77 ± 0.88 | 0.936 | +0.11 ± 0.62 | +0.01 ± 0.83 |
| P value | | 0.072 | <0.001* | | <0.001* | | 0.102 | 0.072 |

*Values less than 0.05 represent a significant difference between the groups according to the ANOVA test.
# Values less than 0.05 represent a significant difference between the physiological parameters in different examination times according to paired samples *t*-test.
In each row, different lower-case letters represent the result of the pairwise comparison between the groups according to the Tucky's post-hoc test ($p < 0.05$).

**Table 4**
Reported pain after 24 h.

| Pain | $N_2O/O_2$ N (%) | Hypnosis N (%) | CBG N (%) | P value |
|---|---|---|---|---|
| Presence | 11 (50) | 6 (27.3) | 10 (45.5) | 0.268 |
| Absence | 11 (50) | 16 (72.7) | 12 (54.5) | |
| Total | 22 (100) | 22 (100) | 22 (100) | |

### 3.5. Correlation between the variables

Spearman's test revealed a very strong correlation between VCAS and VCCS ($r = 0.863$; $p < 0.001$). Moderate correlations were found between VPT and VCAS ($r = 0.568$; $p < 0.001$) and VCCS ($r = 0.565$; $p < 0.001$). The correlations of HR changes with VCAS ($r = -0.251$; $p = 0.004$), VCCS ($r = -0.207$; $p < 0.017$), and VPT ($r = -0.222$; $p = 0.01$) were relatively low. The correlation between CFSS-DS and MCDASf indices was also low ($r = 0.295$; $p = 0.016$).

## 4. Discussion

The findings of the current study indicate that hypnosis and $N_2O/O_2$ inhalation were more effective in reducing anxiety and improving cooperation among participants than conventional behavior guidance (CBG). While half of the participants in the CBG group experienced moderate to severe anxiety, none of the participants in the hypnosis or $N_2O/O_2$ inhalation groups showed severe anxiety.

### 4.1. The rationale for patients' selection

Age is a significant criterion for hypnosis. School-aged children between 6 and 10.5 years were enrolled in the study. Dental anxiety often begins in childhood, so investigating anti-anxiety techniques in children could prevent dental anxiety from extending into adulthood [19]. Dental fear and anxiety tend to increase between the ages of seven and nine. Furthermore, the minimum effective age for hypnosis treatment is identified as six years, and children are more likely to be responsive to hypnosis between 7 and 14 years of age [20]. Groups were also standardized regarding gender distribution since a significant correlation exists between anxiety levels and gender [21]. Female gender is considered a factor influencing clinical hypnosis outcomes [22].

Factors such as the jaw requiring treatment and the injection administered were also standardized. Buccal infiltration injections are generally less painful than palatal injections and mandibular nerve blocks [23]. 'Belonephobia,' or the fear of needles, is a common cause of dental anxiety in children and adults [24]. Given that tooth extractions often provoke fear or pain in children [25], this study included children undergoing extraction procedures.

### 4.2. The rationale for anxiety and cooperation assessment tools

Child baseline anxiety is another major factor influencing the outcome of hypnosis [22]. Therefore, participants' preoperative anxiety levels were carefully investigated to include only children with mild to moderate anxiety. Measuring pre- and postoperative anxiety levels using various indices was among the strengths of this study. In most studies, initial anxiety levels were not considered, and uncooperative behavior was the inclusion criterion [26,27]. However, fear and anxiety are only partial contributors to uncooperative behavior in children [28]. Due to the multidimensional nature of stress, it is recommended to use several methods to measure preoperative anxiety [29]. Moreover, due to the subjectivity of anxiety, a child's fear could be underestimated by parents. Therefore, using multiple anxiety assessment techniques provides a better understanding of the child's fear [30]. In this study, a self-report questionnaire (MCDAS(f)) and the CFSS-DS questionnaire filled out by parents were used. The MCDAS(f) has been tested in studies with children between 5 and 10 [15]. Its ease of use, test-retest reliability, and validity have been demonstrated for children aged 8–15 [31]. Moreover, it can identify specific fears, such as the fear of burs or injections [31]. The CFSS-DS index covers most aspects of dental treatments, and its validity and reliability have been reported [27]. The correlation between the CFSS-DS and MCDASf indices was low ($r = 0.295$; $p = 0.016$). Turner et al. [32] reported similar findings ($r = 0.29$). According to these findings, parents seem to overestimate their child's anxiety [33]. Therefore, it is necessary to employ different scales to include participants with strict criteria.

Participants' postoperative anxiety and cooperation were also measured using several scales. The VPT, a validated self-report tool, effectively measures children's state anxiety [34]. It is simple to explain to children as young as 3, takes less than 2 min, and demonstrates strong internal consistency for children aged 3 to 8 [29]. Self-reporting is particularly significant for children aged six and older [35]. VCAS and VCCS are the most reliable indicators for measuring a child's situational anxiety and cooperation [36]. These scales were also used to assess children's preoperative anxiety levels in previous studies [37].

Physiological indicators, such as HR and $SpO_2$, also offer a comprehensive perspective on anxiety parameter changes across different situations. Kalra et al. [38] showed a positive correlation between dental anxiety and HR and between $SpO_2$ and high levels of anticipatory dental anxiety. However, Manepalli et al. [39] found a very weak negative correlation between HR and MCDAS(f) values. $SpO_2$ was also reported to be an unreliable anxiety indicator. Similarly, in the current study, HR changes showed a relatively low correlation with VCAS, VCCS, and VPT. Therefore, physiological measures should be used as adjunctive rather than primary indicators

to assess the effectiveness of behavioral interventions.

### 4.3. Interventions' effect on anxiety and cooperation level

In our study, participants who received $N_2O/O_2$ or hypnosis reported significantly lower self-reported anxiety (VPT) and observed anxiety (VCAS) scores compared to those in the CBG group. Additionally, the cooperation level (VCCS) in the $N_2O/O_2$ group was significantly higher than in the CBG group. While the VCAS scores in the hypnosis group were higher than those in the CBG group, they were comparable to those in the CBG and $N_2O/O_2$ groups.

Several studies have reported anxiolytic efficacy of hypnosis for pediatric patients. Sola et al. [12] found that hypnosis is a viable and accepted alternative to general anesthesia for children aged 7–16 undergoing superficial surgeries, reducing hospital stays and preoperative anxiety. Furthermore, using hypnosis alongside $N_2O/O_2$ and/or midazolam has eliminated the need for general anesthesia in children over six years old undergoing diagnostic procedures like esophagogastroduodenoscopy or rectosigmoidoscopy [40]. In dentistry, several studies have investigated the effect of hypnosis in conjunction with other methods. For instance, combining low-dose midazolam with hypnosis during restorative treatments and tooth extractions has reduced patients' discomfort [10]. Most studies have focused on patients' pain and anxiety during anesthesia injection rather than dental extraction. Huet et al. [13] reported lower anxiety scores in the hypnosis group compared to the control group, with significantly more children in the hypnosis group experiencing no or mild pain. Oberoi et al. [8] observed that children aged 6 to 16 under hypnosis showed less resistance to dental anesthesia, and Gokli et al. [41] noted reduced crying in children receiving local anesthesia when they underwent hypnosis. Similarly, our findings showed that children in the hypnosis group exhibited significantly better cooperation and lower self-reported anxiety levels than the CBG group during injection. Studies have primarily used subjective scales to assess dental anxiety. However, in the present study, children were carefully monitored during the treatment session, with several indices checked alongside physiological changes. Regarding tooth extraction, Sabherwal et al. [9] found that hypnosis and Progressive Muscle Relaxation reduced anxiety more effectively than CBG.

Hypnotic suggestions are effective tools for reducing anxiety by influencing patients' thinking, behavior, and perception [42]. According to the American Psychological Association (APA), hypnosis is "a state of consciousness involving focused attention and reduced peripheral awareness characterized by an enhanced capacity for response to suggestion" [43]. Halsband et al. [44] investigated the effect of hypnosis on patients with dental phobia using functional magnetic resonance imaging (fMRI). They applied animated audio-visual pseudorandomized strong phobic stimuli and observed brain activity changes. They found that neuronal activity increased in the left amygdala and bilaterally in the anterior cingulate cortex, insula, and hippocampus. During hypnosis, reduced activation in all of these areas was observed, suggesting that hypnosis inhibits the reaction of fear circuitry structures. Children are particularly receptive to hypnosis due to their high imaginative capabilities [41]. While hypnosis has shown promise in pediatric dentistry, it is not widely used due to a lack of training, absence in university curricula, and perceptions of being time-consuming [45]. Contrarily, hypnosis is cost-effective [46], risk-free, and does not require special equipment or drugs. It is also environmentally friendly and free of side effects [47].

To the best of our knowledge, our study is unique in comparing the efficacy of hypnosis with $N_2O/O_2$ inhalation in pediatric medicine and dentistry, revealing similar levels of anxiety and cooperation among the groups. Nathan et al. [48] demonstrated that $N_2O/O_2$ can alleviate mild to moderate anxiety and uncooperative behavior in patients during stressful dental treatments. The anxiolytic effect of $N_2O/O_2$ involves the activation of Gamma-aminobutyric acid type A (GABAA) receptors through the benzodiazepine binding site [49]. However, $N_2O/O_2$ inhalation has limitations, including the need for specialized equipment, trained personnel, specific patient selection criteria, and contraindications for those with certain respiratory conditions. There are also risks of cross-contamination and additional sterilization investments. Repeated exposure to $N_2O/O_2$ can lead to neurological or hematological issues [50,51]. Furthermore, during situations like the COVID-19 pandemic, respiratory distress or congestion may limit the use of $N_2O/O_2$ sedation [50]. Sedation ranges from mild to deep, and there is a risk of unintentionally transitioning to a deeper level of sedation, potentially leading to loss of airway protection reflexes, respiratory depression, and hemodynamic instability [40]. Therefore, hypnosis offers a promising alternative for managing anxious children in dentistry. It is suggested that dentists and dental clinic staff be trained in hypnosis, which requires adapting the treatment environment to reduce external stimuli and create a tranquil atmosphere.

### 4.4. Interventions' effect on physiological parameters

In our study, participants in the $N_2O/O_2$ group showed negligible changes in HR from baseline values, whereas HR in the hypnosis and CBG groups increased during the intervention. Contrary to our findings, Sabherwal et al. [9] reported that hypnosis reduced patients' HR. A review study indicates that there is currently no consensus on the effect of hypnosis on HR [52]. Similar to our findings, Sabherwal et al. [9] reported that changes in $SpO_2$ levels were comparable across all groups.

The HR change was comparable between the hypnosis and CBG groups. Unlike our findings, Girón et al. [53], who studied children aged 5–7 years undergoing pulpotomies, reported significantly lower HR in the hypnosis group compared to the CBG group. However, their participants' baseline HR was lower than in the current study (approximately 88.5 versus 103), which might be attributed to the difference in treatment types. On the other hand, Ramírez-Carrasco et al. [42] found no significant difference in anxiety levels between children receiving hypnosis combined with CBG and those receiving CBG alone. They also did not isolate the effect of hypnosis separately.

### 4.5. Interventions' effect on pain level

Post-extraction, participants in the hypnosis group received hypnotic conditioning with suggestions aimed at eliminating pain for 24 h. Consequently, 72 % of patients in the hypnosis group reported no pain the day following treatment, a higher percentage than in the other groups. Previous research has shown that preoperative hypnosis can lead to lower postoperative pain and a reduced need for painkillers [54].

The number of participants in the CBG group experiencing pain being twice that of the hypnosis group. Lower pain levels following hypnosis were reported in other studies [9,13]. Conversely, Ramirez-Carrasco et al. [42] found no significant differences in pain between hypnosis and control groups during dental procedures in children. However, in the current study, we evaluated pain experience a day after the procedure.

### 4.6. Limitations

This study, however, had some limitations. It did not include children with severe anxiety. Due to the necessity of a mask in the $N_2O/O_2$ group and the presence of a hypnotist in the hypnosis group, blinding of the main operator and assessors was not possible. Nevertheless, highly experienced assessors rated participants' anxiety and cooperation levels separately by watching video-recorded treatment sessions, using an objective index based on the child's facial expressions, movements, and verbal reactions. Moreover, participants were included in the study based on the same inclusion criteria regarding hypnotizability and anxiety, and both patients and their parents were blinded to the study groups. Therefore, rigorous efforts were made to minimize any sources of bias.

## 5. Conclusion

Children who received hypnosis and $N_2O/O_2$ inhalation showed comparable levels of anxiety and cooperation during injection and dental extraction. Moreover, these groups achieved more favorable results than those who received conventional behavior guidance (CBG). $N_2O/O_2$ inhalation has some limitations, including the need for specialized equipment and trained personnel. In contrast, hypnosis has no side effects and does not require special equipment, making it an efficient and safe alternative to $N_2O/O_2$ inhalation for school-aged children with low-to-moderate anxiety undergoing primary tooth extraction.

However, further research is necessary to evaluate the efficacy of hypnosis compared to other sedative drugs and general anesthesia, particularly in participants with different anxiety levels and those receiving various dental treatments. Additionally, the anxiolytic effect of hypnosis should be assessed and compared in dental treatments that require multiple sessions.

## Data availability statement

Data included in article/supp. material/referenced in article.

## CRediT authorship contribution statement

**Afsoon Motallebi:** Writing – original draft, Investigation, Data curation. **Mehdi Fathi:** Writing – review & editing, Methodology, Conceptualization. **Fatemeh Mazhari:** Writing – review & editing, Methodology, Investigation, Formal analysis, Conceptualization. **Melika Hoseinzadeh:** Writing – original draft, Methodology, Formal analysis. **Iman Parisay:** Writing – review & editing, Supervision, Methodology, Investigation, Funding acquisition, Conceptualization.

## Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

## Acknowledgements

This article was extracted from a doctoral thesis (code: 688), and the authors would like to thank the Research Deputy of Mashhad University of Medical Sciences for financially supporting the study (No.: 961714).

## Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.heliyon.2024.e35223.

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