Clinical Effects of Nitrous Oxide Conscious Sedation in Children

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Abstract

Purpose: This study examined the clinical effects of nitrous oxide conscious sedation on children.

Methods: Fifty-nine healthy children (ages 4 to 13, mean age=7.7 yrs.) requiring dental restorative treatment with nitrous oxide sedation were studied. The behavior and clinical effects were assessed before and 5 minutes after 50% nitrous oxide sedation. In addition, the children were instructed to draw 4 selected figures from the Bender Visual Motor Gestalt Test to evaluate psychomotor performance and report on their perceived feelings with nitrous oxide. The total sample was divided into various groups for analysis by age, gender, and prior nitrous oxide experience.

Results: The most common effects of nitrous oxide sedation were open hands (90%), limp legs (81%), and facial smile (66%). Almost all of the children (95%) liked the nitrous oxide, and 86% reported feeling different. In the measure of psychomotor performance, 75% of the children had 2 or less errors initially and 5 or less errors with nitrous oxide.

Conclusions: There are observable signs and perceived symptoms of nitrous oxide conscious sedation in children. In addition, nitrous oxide at a concentration of 50% has a small but significant effect on the psychomotor ability of children. (*Pediatr Dent.* 2004;26:29-36)

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Since the introduction of nitrous oxide into dentistry by Horace Wells in 1844, the drug has become increasingly popular for the management of dental anxiety. Nitrous oxide produces "relative analgesia," a term which was defined by Langa (1976) as "a chemically induced altered psychological state which eliminates the fear and pain of the dental experience."[1] There have been numerous studies which presented evidence regarding the safety and efficacy of nitrous oxide in reducing anxiety during dental treatment.[2-7] In addition, the quality of rapid onset and reversal for the analgesic and relaxant properties have made nitrous oxide an integral component of dental practices throughout the United States. A survey by Wilson in 1996 of 1,758 diplomates of the American Academy of Pediatric Dentistry indicated that 89% reported the use of nitrous oxide in their practices as an adjunct to behavior management techniques.[8]

Many different studies of nitrous oxide have examined the physiological, anxiolytic, behavioral, psychomotor, and analgesic effects of nitrous oxide in both children and adults. The majority of these studies utilized objective observation in their assessment of nitrous oxide effects. There were, however, few studies that reported on the effects from the child's perspective. Children described dreaming and headache with nitrous oxide in a study by Hogue et al.[6] In another study by Berger et al,[4] some children reported a "floating, warm, and tingling sensation" with nitrous oxide.[4] In yet another study, children reported a preference for music in conjunction with nitrous oxide during dental treatment.[2] The child's perspective also was considered in a study of analgesia with nitrous oxide when the child's perception of pain was measured by the use of a self-report color scale.[9]

There have been studies that reported on the psychomotor effects of nitrous oxide in adults and children.[10-16] Psychomotor impairment is an important indicator of drug effect and recovery from a drug.[17] Psychomotor effects were evaluated with a modified Bender Visual Motor Gestalt Test. Impairment was demonstrated in fine motor skills with nitrous oxide in adults and children.[13,16] Tracing geometric figures was used to evaluate perceptual motor effects, and psychomotor impairment was observed.[14] Despite the numerous studies with nitrous oxide in children, there were few studies that report the subjective responses by children or the psychomotor effects for children under 7 years of age. Furthermore, the literature is deficient in the documentation of the clinical objective signs and subjective symptoms expressed by children with nitrous oxide. The objective of this study was to report on the clinical signs and symptoms of nitrous oxide conscious sedation in children. In addition, the effects of nitrous oxide on the psychomotor ability of children were examined.

Methods

This study was approved by the University of Medicine and Dentistry of New Jersey (UMDNJ) Institutional Review Board. A convenience sample of 59 children (36 males and 23 females, age 4 to 13 years, mean age= 7.7 years) requiring restorative dental treatment with nitrous oxide were selected for study. Selection criteria included:

1. no sensory or cognitive impairments;
2. the capability to draw at least 1 figure on the psychomotor evaluation component;
3. indication for and no contraindication to the use of nitrous oxide conscious sedation.

Fifty-four children were treated in 4 private pediatric dentistry offices in New Jersey, and 5 children were treated at the UMDNJ-New Jersey Dental School pediatric dentistry clinic. For analysis, the children were subdivided into 3 age groups, with a balanced distribution of gender between the age groups:

1. 4 years and 4 months to 6 years and 4 months (N=20);
2. 6 years and 5 months to 9 years (N=19);
3. 9 years and 1 month to 13 years (N=20).

Furthermore, the sample consisted of 36 children with some prior nitrous oxide experience and 23 children for whom the visit was their first nitrous oxide experience.

Each child participated for only 1 session in this study. After consent to participate in the study was obtained from their parents, the selected children were given nitrous oxide as part of the standard procedure, as determined by the individual practitioner providing the dental treatment. The children were brought into the dental operatory and their behavior was rated with the Frankl scale before the treatment was started. Baseline clinical objective signs were recorded, and the children were then asked questions in a standardized manner regarding their perception of their overall preoperative condition.

The children were then asked to draw selected figures from the Bender Visual Motor Gestalt Test (Figure 1).[18] Nitrous oxide was then administered at a 50% concentration for 5 minutes, and the evaluation was repeated. The clinical signs and behavior rating were recorded, and the children were asked about their perception of the nitrous oxide symptoms. Visual motor coordination was reevaluated with the Bender Visual Motor Gestalt Test figures. The practitioner then administered the local anesthetic and proceeded with the planned restorative dental treatment. One independent observer (RL) conducted the evaluation with the response rating form and the visual motor coordination test for all subjects. Each child served as his/her own control with observations made before and during nitrous oxide administration.

Objective signs

Objective signs were recorded prior to and 5 minutes after nitrous oxide administration. These signs assessed the clinical features and condition of the patient's face, hands, legs, and feet to determine the effects of nitrous oxide. The following signs were examined: (1) open or closed eyes; (2) tears; (3) trance-like expression; (4) smile; (5) speaking; (6) laughing; (7) open or closed hands; (8) limp legs; and (9) abducted feet.

Subjective symptoms

Subjective symptoms addressed the child's perception of the nitrous oxide effects. Questions regarding the child's perception of the nitrous oxide effects on the head, abdomen, fingers, toes, and overall condition were asked prior to and 5 minutes after nitrous oxide administration. The questions were:

1. How do you feel?
2. Do you feel different?
3. Do you like the funny air?
4. Does your lip feel different?
5. How does your head feel?
6. How does your belly feel?
7. How do your fingers feel?
8. How do your toes feel?

The following choices were given for the questions that addressed the head, abdomen, fingers, and toes: (A) OK; (B) tingly; (C) warm; (D) cold; (E) light; and (F) heavy. The overall condition response choices were: (A) good; (B) bad; (C) sleepy; and (D) OK.

Psychomotor effects

Four figures were selected from the Bender Visual Motor Gestalt Test[18] to study the effects of nitrous oxide on the psychomotor ability of children (Figure 1). All children were asked to draw these figures, to the best of their ability, before and 5 minutes after nitrous oxide was administered. The figures varied in level of difficulty, which paralleled the sensory motor ability of the age ranges selected for the study. Different levels of difficulty were selected to make the drawing task more sensitive to nitrous oxide effects. Furthermore, the wider range of difficulty

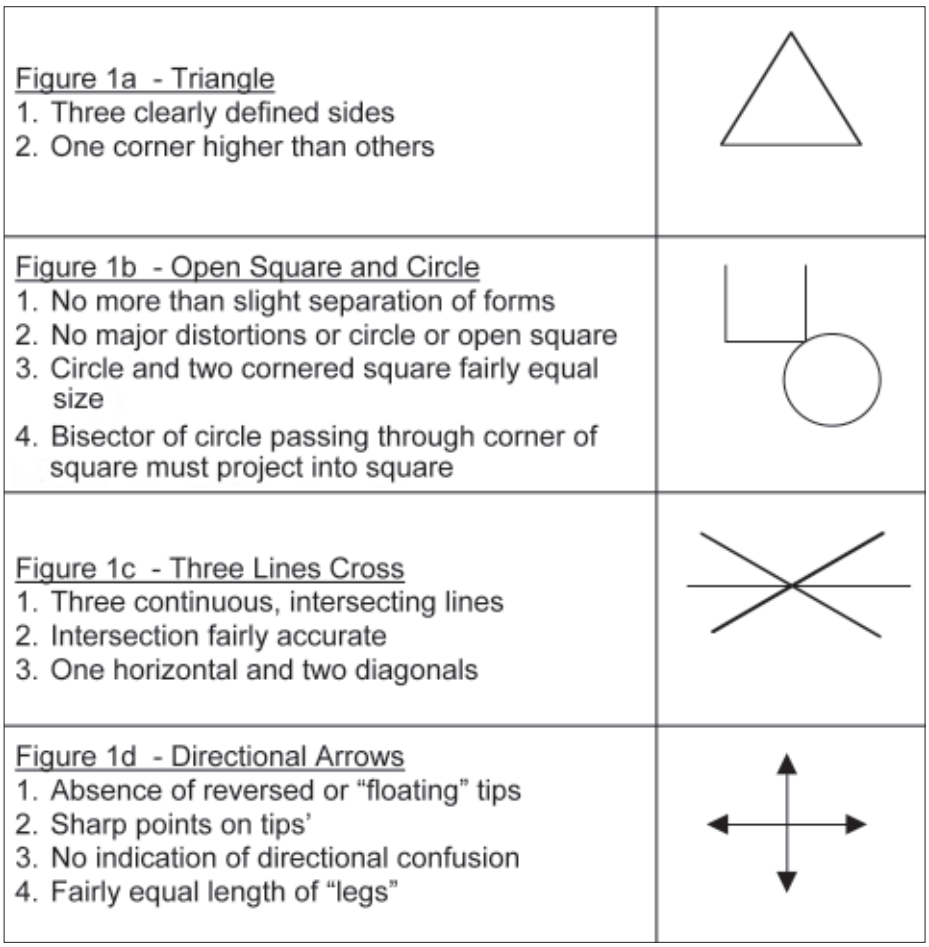

Figure 1. Beery criteria for correct drawing of selected figures of the Bender Visual Motor Gestalt Test.[18]

allowed an evaluation of children with different ages and visual motor capability. The figures were scored independently by 2 examiners according to the criteria established in the Test of Visual-Motor Integration.[19]

An adaptation of Beery's scoring method was made to facilitate the measurement of nitrous oxide effects across the entire sample. Any error in a particular criterion was given the same weight. Therefore, the score did not reflect a developmental level as Beery had established. The score reflected the number of errors in the figure or the number of conditions to draw the figure successfully that were not satisfied by the child's drawing. Delta N represented the psychomotor performance changes due to nitrous oxide and was equal to the total number of errors with nitrous oxide minus the total number of errors before nitrous oxide was started. This corrected for any errors that may have occurred as a result of the child's initial inability to draw the figure and helped to isolate any psychomotor effects that resulted from nitrous oxide.

Results

The frequencies of the objective signs and subjective symptoms are presented as the actual number of frequencies and as proportions of the total sample (N=59) in Tables 1 and 2. In this sample, children presented with good behavior ratings during nitrous oxide administration, rating 3 (44%) and rating 4 (56%) on the Frankl Rating Scale. Furthermore, the few children who had presented to the dental appointment with tears prior to nitrous oxide (5%) did not present tears during the nitrous oxide administration.

Objective signs

The presence of open hands (90%) was the most common objective sign with nitrous oxide in the total sample. This was followed by limp legs, which was observed in 81% of the children. Furthermore, abduction of feet was observed in 31% of the children with nitrous oxide, where the toes faced in a lateral direction. Smiling and a trancelike expression (where the child appeared to stare blankly into space) were observed in 66% and 44% of the children, respectively. Laughter with nitrous oxide occurred in only 14% of the sample. When the laughing was

Table 1. Occurrence of Objective Signs (N=59)

Clinical sign	N prior to N_2O (% of total)	N during N_2O (% of total)
Behavior rating 1	1 (2)	0 (0)
Behavior rating 2	6 (10)	0 (0)
Behavior rating 3	52 (88)	26 (44)
Behavior rating 4	0 (0)	33 (56)
Eyes open	59 (100)	55 (93)
Tears	3 (5)	0 (0)
Trancelike expression	0 (0)	26 (44)
Smile	0 (0)	39 (66)
Speaking	7 (12)	9 (15)
Laughing	0 (0)	8 (14)
Hands open	32 (54)	53 (90)
Legs limp	13 (22)	48 (81)
Feet abduction	9 (15)	18 (31)

Table 2. Occurrence of Subjective Symptoms (N=59)

Clinical symptom	N prior to N_2O (% of total)	N during N_20 (% of total)
Feel good	13 (22)	41 (70)
Feel bad	5 (8)	1 (2)
Feel sleepy	0 (0)	6 (10)
Feel OK	41 (70)	11 (18)
Feel different	*	51 (86)
Like N_2O	*	56 (95)
Sensation in lip	*	34 (58)
Head		
OK	59 (100)	25 (42)
Tingly	0 (0)	15 (25)
Warm	0 (0)	5 (8)
Cold	0 (0)	0 (0)
Light	0 (0)	11 (19)
Heavy	0 (0)	3 (6)
Abdomen		
OK	59 (100)	34 (58)
Tingly	0 (0)	16 (28)
Warm	0 (0)	5 (8)
Cold	0 (0)	0 (0)
Light	0 (0)	2 (3)
Heavy	0 (0)	2 (3)
Fingers		
OK	59 (100)	25 (42)
Tingly	0 (0)	27 (46)
Warm	0 (0)	5 (8)
Cold	0 (0)	0 (0)
Light	0 (0)	1 (2)
Heavy	0 (0)	1 (2)
Toes		
OK	59 (100)	30 (51)
Tingly	0 (0)	23 (39)
Warm	0 (0)	3 (5)
Cold	0 (0)	2 (3)
Light	0 (0)	1 (2)
Heavy	0 (90)	0 (0)

*Only applicable with nitrous oxide.

observed, however, it appeared that the laughter was difficult for the children to suppress and control. Furthermore, the laughing was characterized by a spontaneous nature.

Subjective symptoms

The frequencies of clinical subjective symptoms in the total sample are reported in Table 2. Seventy percent of the children had reported feeling good with nitrous oxide; however, 2% of the children indicated feeling bad. Furthermore, 10% of the children reported drowsiness. Almost all of the children (95%) liked nitrous oxide, and 86% reported feeling different with nitrous oxide.

With nitrous oxide, a variety of sensations in different body parts were reported by the children in this study. A sensation in the lips was indicated by 58% of the sample. A tingly feeling (25%), lightheadedness (19%), or no difference (42%) comprised the majority of head symptoms. The predominant abdominal sensations appeared to be tingling (28%) or no difference (58%). There were some children, however, who reported warmth (8%), lightness (3%), or heaviness (3%). The extremities (fingers and toes) seem to share a predilection for either a tingly sensation or no difference, with 46% of the children reporting a tingly feeling in their fingers and 42% reporting no difference. More children indicated no difference with their toes (51%) than tingling (39%). While the other descriptions (warm, cold, light, and heavy) did not represent a large proportion of the responses, they did occur in the sample (Table 2).

The data was analyzed for differences between subgroups in regard to age, gender, and prior nitrous oxide experience. Few statistically significant findings were evident with all comparisons. Table 3 indicates the between subjects analysis by age of selected subjective symptoms reported during nitrous oxide administration. The values in the table represent percentages of total subjects in each age group that experienced a particular effect. The only statistically significant differences between groups were with feelings of sleepiness and lightheadedness, which were reported with greater frequency in the oldest age group (P=.02).

Table 4 indicates the between subject analysis by prior nitrous oxide experience of selected subjective symptoms reported during nitrous oxide administration. The values in the table represent percentages of total subjects in each group that experienced a particular effect. The only statistically significant differences between groups were with feelings of sleepiness and warmth of fingers and abdomen (P=.04).

Psychomotor effects

The effects of nitrous oxide on psychomotor performance appear in Table 5. That table indicates the number of children who obtained differing numbers of errors before nitrous oxide. In addition, the table reports the mean number of errors performed with nitrous oxide according to the numbers of errors performed before nitrous oxide. The results indicated that nitrous oxide had a small but significant effect on the ability of the sample to reproduce the figures in the psychomotor evaluation (F=12.52, df=8, P<.001). Generally, the children who produced fewer errors without nitrous oxide, produced noticeably fewer errors with nitrous oxide. The majority (75% of the group, N=59), had 2 or less errors without nitrous oxide initially and 5 or less errors with nitrous oxide. Those who initially

Table 3. Between-subject Analysis of Age Group of Selected Subjective Symptoms During Nitrous Oxide*

Subjective symptom with N_20	% of group 1 (4 yrs, 4 mos–6 yrs, 4 mos) N=20	% of group 2 (6 yrs, 6 mos–9 yrs) N=19	% of group 3 (9 yrs, 1 mo–13 yrs) N=20	Chi-square value	*P* value
Feel good	65	89	55	5.75	.06
Feed bad	5	0	0	1.98	.37
Feel sleepy	0	6	25	7.58†	.02†
Feel OK	30	5	20	3.97	.14
Feel different	75	89	95	3.63	.16
Like N_2O	95	100	90	2	.36
Sensation in lip	60	63	50	0.76	.68
Head					
Tingly	40	20	15	3.58	.17
Warm	10	5	10	0.37	.83
Light	0	21	35	8.18†	.02†
Heavy	0	5	10	2.07	.35
Abdomen					
Tingly	35	16	30	1.94	.38
Warm	20	5	0	5.53	.06
Light	0	5	5	1.06	.59
Fingers					
Tingly	35	47	55	1.64	.44
Warm	20	0	5	5.49	.06
Toes					
Tingly	35	53	60	2.30	.32
Warm	10	0	5	2.02	.36
Cold	0	0	10	4.04	.13

*Values are percentages of subjects in group.
†Statistically significant (*P*<.05).

had 5 or more errors without nitrous oxide had significantly greater numbers of errors with nitrous oxide. That subset represented 7% of the total group and demonstrated a mean error of 8±3.3 after nitrous oxide was given.

The data was analyzed for any significant influence on psychomotor performance of gender, age, prior experience with nitrous oxide, or initial behavior. In general, there were no significant effects of any of these independent variables. In regard to gender, the mean differences in total psychomotor scores with and without nitrous oxide were 1.7±2.4 for males and 0.95±1.9 for females, and those differences were not statistically significant. There were also no statistically significant effects of prior nitrous oxide on psychomotor performance with nitrous oxide. A Pearson correlation analysis indicated that initial behavior did not have any significant impact upon psychomotor changes with nitrous oxide (*r*=-0.07, *P*=.43).

The effects of age groups on the performance differences with nitrous oxide are shown in Figure 2. There were differences between age groups before nitrous oxide and between age groups after nitrous oxide since young children have less dexterity and produce more errors in figure drawing than older children. There was for all groups a mean total difference of 1.4±2.2 and a range of performance differences of -5 to 8 (F=1.27; *P*=.28). The increase in numbers of errors from before to after nitrous oxide (delta N) was similar for each of the 3 age groups. Consequently, there were no statistically significant differences between age groups in psychomotor performance.

Discussion

This study examined the clinical signs, perceived symptoms, and psychomotor effects of nitrous oxide conscious sedation in children from 2 different perspectives: an independent observer and that of a child. Some previous studies attempted to examine the child's perception of nitrous oxide sedation,[2,4,6] however, those attempts were not very extensive, as they were not the focus of the cited studies. This study utilized the child's responses to various questions concerning the nitrous oxide experience to assess the various symptoms.

Table 4. Between-groups Analysis by Prior Nitrous Oxide Experience of Selected Subjective Symptoms During Nitrous Oxide*

Subjective symptom with N_20	% of sample with prior N_20 N=36	% of sample without prior N_20 N=23	Chi-square value	*P* value
Feel good	69	70	0	0.99
Feel bad	6	13	1.02	0.31
Feel sleepy	16	0	4.26†	0.04†
Feel OK	14	26	1.38	0.24
Feel different	86	87	0.01	0.92
Like N_20	97	91	1.02	0.31
Sensation in lip	50	70	2.2	0.14
Head				
Tingly	17	39	3.74	0.06
Warm	11	4	0.82	0.36
Light	22	13	0.78	0.38
Heavy	8	0	2.02	0.15
Abdomen				
Tingly	22	34	1.12	0.29
Warm	3	17	3.86†	0.04†
Fingers				
Tingly	47	43	0.08	0.78
Warm	3	17	3.86†	0.04†
Toes				
Tingly	36	43	0.32	0.57

*Values are percentages of subjects in groups.
† Statistically significant ($P<.05$).

It is important to note that most of the children had positive attitudes toward dental procedures. Other results might have been found if subjects initially exhibited negative or extremely fearful behavior.

The subjective reports illustrated the nitrous oxide effects from the child's perspective. Overall, the variety of sensations in the different body parts are in some ways similar to those reported by Langa (1976)[1] in adults. It was interesting to find that 42% of the children reported feeling no difference in their head with nitrous oxide. In contrast, 25% of the sample reported a tingly head sensation and 19% lightheadedness, which was in accordance with the findings of Hogue et al (1971),[6] and Berger et al (1972),[4] with respect to head symptoms. Several possible reasons could explain the differences reported with the head sensation. There exists the possibility that the children of the younger age group lacked the understanding of lightheadedness or tingliness. Also, it is possible that the children felt a variety of sensations in their head and had difficulty explaining what it is that they were feeling. The choices presented to the children aided their descriptions; whether or not the choices were fully comprehended by the younger children remains questionable.

While the children reported various symptoms with nitous oxide, the majority of the children (86%) reported feeling different overall with the gas. Ninety-five percent of the children liked the feelings, and 70% reported feeling good with nitrous oxide. Such findings contribute greatly to the success of nitrous oxide as an adjunct to behavior management in dentistry. Acceptance of nitrous oxide is an important factor; the sedation procedure is more likely to be effective with behavior and apprehension if the administration of the agent is uncontested.

As anticipated, there were no significant differences between males and females for the subjective symptoms. An interesting age group difference was related to the feelings of drowsiness and lightheadedness. The results indicated that children older than 6 years and 6 months reported a significantly higher occurrence of drowsiness and light-headedness. A possible reason for this finding is that the younger children might not have

Table 5. Effect of Nitrous Oxide on Psychomotor Performance

Total no. of errors before N_20	No. of children	Mean no. of errors* ±SD with N_20
0	20	1.6±2.4
1	12	3±1.6
2	12	3±1.3
3	4	4.3±1.3
4	1	1
5	5	8.3 ±3.3
9	1	11
11	3	10±3.4
13	1	13

* Mean number of errors performed with nitrous oxide, according to number of errors performed before nitrous oxide.

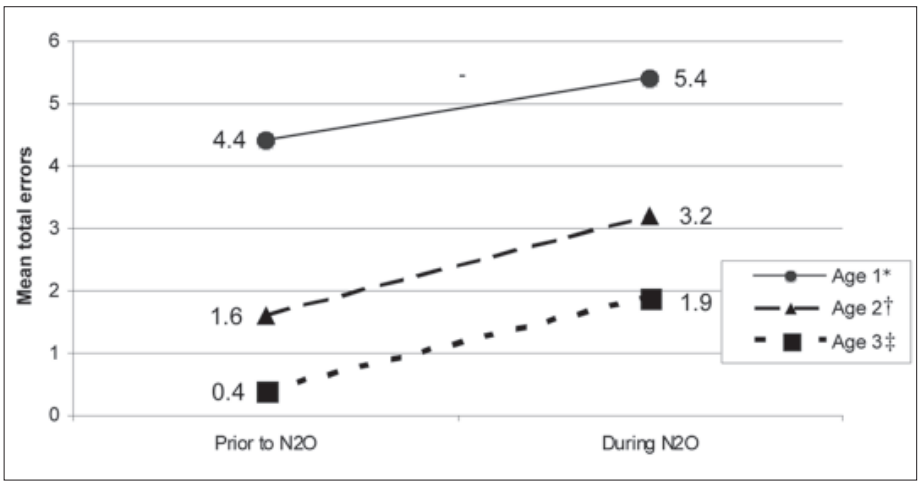

Figure 2. Mean errors prior to and during nitrous oxide by age group.
*Age 1=4 years, 4 months-6 years, 4 months (N=20).
†Age 2=6 years, 5 months-9 years (N=19).
‡Age 3=9 years, 1 month-13 years (N=20).

understood the term "light" as a description for a feeling in the head. Furthermore, it is likely that the older children might have been more selective with the adverb chosen to describe the feeling as a result of a more extensive vocabulary.

Another interesting finding was that a significantly higher frequency of reported feelings of sleepiness and warmth was observed with children with previous nitrous oxide experience. This was possibly due to the fact that the children with previous nitrous oxide experience are already familiar with the apparatus and experience and are more accepting of the nitrous oxide effects. From the child's perspective, it appears that nitrous oxide has a relaxing effect, especially in older children and with those who have had nitrous oxide on a previous occasion.

The psychomotor evaluation of this study was adapted so that younger children could be assessed. While other studies[13,22] utilized Trieger's adaptation of the Bender Visual Motor Gestalt Test[15,16] for children as young as age 4, early trials of Trieger's methods for this study found the adaptation too difficult for children under 6 years of age. Children as young as 4 years and 4 months were capable of drawing the figures with an adaptation of the Beery scoring method for the Bender Visual Motor Gestalt Test[18,19] used in this study. Nevertheless, there was still difficulty with comparison of the results of the younger children with those of the older children. Younger children are not as mature in their visual motor coordination as older children are, and this presents a problem when the actual effects of the nitrous oxide on performance change are investigated. To facilitate the analysis, delta N, representing the difference in psychomotor performance, was evaluated. This value isolated the effects of nitrous oxide from the effects of age. Overall, the mean number of errors was consistently higher with nitrous oxide than without. These findings are in agreement with those of previous studies[13-15] despite the fact that other evaluation methods were utilized in these. However, the effects of 50% concentration of nitrous oxide were not as profound as was anticipated. Perhaps, this might have been due to the fact that fine visual motor coordination could not be assessed with the psychomotor evaluation instrument used in this study. It also could be due to a small effect of the gas at that concentration on psychomotor performance.

This study investigated the clinical signs and symptoms of nitrous oxide in children to provide information that could aid in determining when an appropriate nitrous oxide dosage for dental treatment is reached. The findings of this study give a better understanding of the feelings that a child experiences during nitrous oxide conscious sedation. Future studies are needed to document the effects of nitrous oxide in those children who are highly apprehensive and exhibit defiant behavior. It is also necessary to investigate the effects of nitrous oxide in children as young as 2 years of age. Such studies would help to establish realistic expectations of the value of nitrous oxide and diminish the believe that it is a panacea for all apprehensive children. A better understanding of the clinical signs and perceived effects of nitrous oxide in children will lead to proper use of the drug and subsequently heighten its effectiveness.

Conclusions

1. There are observable objective clinical signs of nitrous oxide conscious sedation in children. In addition, children report differences in their subjective symptoms with nitrous oxide conscious sedation.
2. Nitrous oxide has a small but significant effect on the psychomotor ability of children at 50% concentration.

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Abstract of the Scientific Literature

Salivary pH Changes Associated With Soft Drinks

There seems to be an increase in dental erosions in Argentina, perhaps partly due to an increase in the consumption of soft drinks. The aim of this case-control study was to measure salivary pH, flow rate, and buffering capacity before and after soft drink consumption in children with and without erosive lesions. Thirty children with erosion were age- and sex-matched with 30 children free from erosion and cavities. Salivary flow rate, pH, and buffering capacity were measured using standard salivary tests. Results showed that, prior to the consumption of soft drinks, salivary flow rate, pH, and buffering capacity in the control group were significantly higher compared to the patients with erosion. There was a significant difference between cases and controls for maximum salivary pH drop and minimum salivary pH values following the soft drink intake. It was concluded that all the factors studied were involved in dental erosion.

Comments: It seems that salivary factors play an important role in predisposing individuals to the development of dental erosion. **HA**

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6 references