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Positive Effects of a psychological preparation program for MRI “iMReady” in children with cognitive issues – how to meet the patients’ needs best

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Research Article

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Abstract

Background

A growing body of evidence has supported alternatives to sedation and general anesthesia for increasing treatment compliance of children during MRI examinations. Particularities in children with a brain tumor (frequency of examinations, neuropsychological deficits (attention, memory)) have a significant impact on methods and are given special consideration in this study. The aim of the present study was to (1) evaluate the effectiveness of an MRI training program and to investigate the moderating factors for successful MRI examination for a group of young patients with pediatric brain tumors and/or NF1 and (2) to examine the effect of the training on the patient's well-being.

Methods

A total of 87 patients of the neuro-oncology unit (mean age: 6.83 years) underwent a two-step program to prepare children for MRI, including an in vitro strategy training inside the scanner and were recorded using a process-oriented screening (emotional wellbeing and level of information), which was developed for this purpose. All data was analyzed retrospectively and the data of a subgroup of 17 patients was also analyzed prospectively (ClinicalTrials.gov: NCT04474678).

Results

81% of the children who had received MRI training managed to successfully undergo the MRI scan without sedation and/or anesthesia making the success rate almost five times as high as in the group that did not receive the intervention. Memory, attentional difficulties, and hyperactivity were significant neuropsychological moderators for successful or unsuccessful scanning. Furthermore, the training was effective in improving the psychological well-being of the patients.

Conclusion

Based on the results, the MRI training is an effective alternative to sedation of young patients for MRI examinations and a promising tool for improving patient well-being related to the diagnostic procedure. However, specialized psychological staff and an interdisciplinary approach are required to adapt the intervention to the children's individual neuropsychological needs.

Trial registration number:

ClinicalTrials.gov Identifier: NCT04474678

1. Background

Magnetic resonance imaging (MRI) can be a stressful procedure for both children and their parents [1, 2]. The scanning process requires patients to lie motionless in a narrow tube, while the apparatus makes loud noises. Especially young children tend to have difficulties with self-restraint; the longer the procedure, the higher the risk for poor image quality due to motion artifacts, since the amount of patient movement within the scanner determines image quality and accuracy.

One possible strategy to reduce the risk for patient movement in young children is general anesthesia (GA) and sedation. Although serious adverse effects are rare, the risks associated with GA and sedation are well-documented and include respiratory complications, aspiration, cardiac arrest, and vomiting [3, 4]. Furthermore, the sedation process requires additional time for anesthetic introduction as well as highly trained staff and hospital beds for monitoring the patients [5].

A growing body of evidence supports an alternative approach: preparation and training methods show promising results in reducing the necessity of GA in young children [6]. Most studies have focused on how to increase compliance for non-sedated MRIs in different neurological and non-neurological patient groups (e.g., patients with diabetes, sickle-cell-disease, obsessive compulsive disorder, with high risk of developing dyslexia) and healthy controls. However, very young children, children with developmental disorders, attention problems or cognitive issues were often excluded in these samples. Only three studies that included children with attention deficit hyperactivity disorder (ADHD), developmental delay, autism spectrum disorders (ASD), neurological impairment, anxiety, and other problems to lie still, could be identified [7–9]. The results illustrate the need for a differentiated consideration of predicting factors to increase compliance and to successfully comply with an MRI examination.

Cognitive and psychological issues are common and well-documented in pediatric brain tumor survivors and children with neurofibromatosis type 1 (NF-1), who are at an increased risk of developing a brain tumor. These issues include problems with attention, memory, processing speed, visuomotor function, learning difficulties, age related issues, as well as disease related stress factors (such as the recurrent experience of medical procedures) for patients and parents [10–13]. In brain tumor survivors, medical follow-up requires regular MRI procedures, with intervals of 3 to 6 months in the first three years, and 6 to 12 months in the first 10 years following treatment, depending on specific treatment protocols [14]. Tumor surveillance routines for NF-1 patients vary per clinic but in case patients have optic pathway gliomas MRI examinations are recommended every 3 to 6 months [15]. The average duration of an MRI examination for these purposes is 30–60 minutes depending on which body parts need to be examined (brain MRI, brain and spinal cord MRI) [16, 17].

Considering the frequency and duration of MRI examinations, as well as the specific challenges arising due to developmental, cognitive, or emotional issues, it is evident that customized preparation programs are necessary for these children to best meet the patients’ needs and prevent an additional emotional and physical strain on these already challenged patients. Hence, it is more than evident, that children with special issues need tailored programs.

The methods and aims of receding studies on the topic are heterogenous, mostly focusing either on the reduction of sedation rates or on limiting movement artifacts to improve MRI image quality in pediatric patients [8, 9, 21–35]. Preparations with a mock MRI [6–9, 17, 21, 24, 25, 29, 31, 34] or other techniques such as operant conditioning [29], video animation [35, 36], play therapy [23, 28, 36] or animal-assisted therapy [37] to prepare children for an MRI as well as exposure to distracting techniques before [35] and during the MRI scan [22, 26, 27, 32] have been demonstrated to effectively reduce the need for sedation. Besides the manifest benefits of preparation programs on children, indirect effects have been reported, such as elevated sensitivity to the topic in the radiology department [35, 24] and reduced waiting time for MRI due to less patients needing sedation/anesthesia [36]. Little research has been conducted regarding the underlying methods of successful non-sedated MRI and about the effects of MRI preparation programs on the psychological well-being of children undergoing scans. Temperament, medical experience, and parental expectations have been linked to higher MRI success [9]. Furthermore, only a few studies have focused on the reduction of anxiety and distress via appropriate MRI preparation [7, 28, 34, 35, 37, 38].

Thus, the purpose of the present study was to retrospectively evaluate the effectiveness of the MRI training, as well as to investigate the underlying mechanisms for non-sedated MRI success. Furthermore, the psychological effects of the training on its participants were analyzed prospectively to derive specific needs of a neuro-oncological patient group comprised of brain tumor and NF-1 patients.

2. Methods

2.1 Development and content of the training “iMReady”

The first version of the MRI training procedure “iMReady” was originally developed in 2008. Subsequently, it underwent further adaptations before being implemented as a standard of care at our neuro-oncology unit. Its aim was to provide all children and adolescents with anticipatory guidance and developmentally appropriate preparatory information about the MRI. These goals coincide with two standards formulated in 2015 in the Psychosocial Standards of Care Project for Childhood Cancer [18-20]. In line with the approaches discussed in the standards the program addresses a wide variety of psychological concepts with the aim of decreasing the psychosocial challenges caused by medical and diagnostic procedures and to overall increase the compliance in MRI procedures with or without GA. The incorporated concepts include psychoeducation, resource- and solution-oriented techniques, communication techniques, relaxation techniques and reflection. At the beginning of the training, every child receives an MRI training booklet which contains important information about the MRI in a standardized, age-appropriate and visually appealing way. The booklet also provides practical material with enhanced stimulating elements to encourage the child to explore actively and multimodally, thereby equally contributing to the developmental and neuropsychological aspects of learning. Psychoeducational, active, practical, and reflective aspects are covered in two face-to-face training sessions. To reinforce the comprehension of the training process and to promote self-efficacy, the child is encouraged to bring the booklet to every session as well as the diagnostic MRI. In 2017 the training was integrated in a quality improvement project (“Mein

Logbuch - Ich kenne mich aus!"/ "My Logbook - I know my way around!") [39]. This project aims to guide children throughout the entire disease trajectory. As part of this quality improvement project, a delphi survey with interdisciplinary and international experts was conducted in 2017-2018. The results emphasize the necessity of standardized psychological support to enable an evaluation and optimization of psychosocial care. Patient involvement was highlighted and therefore the evaluation of emotional well-being and the degree of knowledge and experienced confidence (evaluated by medical staff and the patients themselves) was included in the study design. Furthermore, the design and practical elements of the booklets were enhanced to make it more stimulating [39].

Considering age, developmental aspects and interdisciplinary evaluation a clinical psychologist or pediatrician decide whether a patient qualifies for an MRI training, children are referred to it during a routine visit in the interdisciplinary outpatient clinic. Parents are informed about the purpose, conditions and procedure of the training and encouraged to actively participate as co-therapists in the training to guarantee transfer and reinforce the effect of the training. The MRI training sessions are performed by an interdisciplinary team of medical doctors, radiologists and nurses, but coordinated by a clinical psychologist trained to consider developmental and motivational aspects and possible cognitive, emotional or social deficits in the participants. During the procedure, the patients' primary care giver(s) are always present.

1. The primary goal of the first session is the psychological and medical preparation, while also discussing the pros and Cons about having the MRI without anesthesia. Hence, additionally to basic information and procedural knowledge about the MRI, instructions for appropriate clothing, metal objects, lying still and the sound of the MRI are discussed with the participants. Role play techniques are used to build and practice coping strategies and action control. In order to further familiarize themselves with the topic, the children receive instructions for exercises, which they are asked to complete at home together with their parents. The homework is composed by two exercises: building a paper MRI model and continuing the role-play techniques with the paper model (figure 1).
2. In session two the topics of the previous session are repeated before self-instruction and relaxation techniques for children are introduced and practiced. Furthermore, children and parents undergo a practice run in a 1.5 Tesla MRI (Siemens Aera). Children and parents can the MRI environment and build a relationship with MRI staff. During the practice run, children and parents can experience the MRI procedure and develop further helping strategies such as the use of additional blankets or pillows, a mirror on the head coil or additional earplugs. One MRI sequence of approximately five minutes is performed, which gives children and parents the opportunity to hear the sound of the magnet and to make a first evaluation about picture quality. In the end children, parents, and the psychologist reflect upon the MRI training and together they decide whether the examination will be done with or without sedation. Children and parents are further instructed to regularly repeat and practice the acquired skills at home, while using relaxation, self-control, and operant techniques. See also for more details figure 1.

2.2 Participants

The study sample for retrospective analysis consisted of 105 patients with a mean age of 6.83 years (*SD* = 2.04; range= 4 to 14). As standard of procedure, all children beginning with the age of four years and older were invited to participate. Since it is expected that especially children with special needs benefit from or require training, there are no specific exclusion criteria. For the 53 female participants (50.5%), mean age was 6.21 (*SD* = 1.64). For male participants it was 7.46 (*SD* = 2.23). The 52 children and adolescents who attended school were on average in second grade (median). The majority of participants spoke German as their first language (66%). For children who did not speak German, non-verbal methods were used or were supported by the translation of the parents. More information on sample characteristics as well as the patients´ medical details can be found in table 1. Most patients (72.69%) suffered from a brain tumor. Mean onset age of the medical condition was at 3.01 years (*SD* = 2.76). All patients that were not affected by a brain tumor had NF1. Of a total of N = 54 patients with NF1, 20% were diagnosed with brain tumor. Of all the participants enrolled in the program, 83% actually received MRI training, while 17% did not, due to scheduling reasons (n=9) or because the parents did not want their children to receive the intervention (n=8). Two subjects participated in the study because NF1 was suspected and thus MRI was indicated. These patients were later excluded from data analysis because further medical examination revealed that they did not suffer from the condition.

As part of the evidence- and consensus-based development of the training, the updated version was deployed in fall 2018: Of 17 patients participating, 10 were female (59%). Mean age was 5.65 years (*SD* = 1.37, range = 4 to 9 years). 12 children spoke German as their first language (71%). 13 patients suffered from a brain tumor (76%), while 4 did not (24%). 8 participants suffered from NF1; 4 of them also had a brain tumor. All patients with brain tumors received oncological treatment according to protocol. All patients attended MRI training; 13 children completed their scans without general anesthesia (76%).

Table 1: Descriptive date (Sociodemographic and medical details)

	Frequency (%)
Sex	
Female	53 (51%)
Male	54 (40%)
First language	
German	60 (57%)
Turkish	5 (5%)
Serbian	3 (3%)
Bosnian	1 (1%)
Polish	1 (1%)
Other	9 (11%)
Bilingual	12 (11%)
Education	
Kindergarten/pre-school	37 (42%)
Primary school	44 (49%)
High school	8 (8%)
Special education needs	
Regular school	34 (74%)
Special education	12 (26%)
Diagnosis	
NF1	33 (31%)
NF1 with low grade glioma	21 (20%)
Low grade glioma	32 (30%)
Other brain tumors	15 (14%)
Other	4 (4%)
Progression of brain tumor	
No	98 (93%)
Yes	7 (7%)
Medication	

None	71 (68%)
Yes	34 (32%)
Medical Therapy	
Observance only	52 (51%)
Surgery only	22 (21%)
Surgery + chemotherapy	6 (5%)
Surgery + chemotherapy + radiation therapy	10 (9%)
Surgery + radiation therapy + chemotherapy + antiangiogenic therapy	2 (2%)
chemotherapy only	10 (9%)
chemotherapy + radiation therapy	2 (2%)
none	

2.3 Design

2.3.1 Retrospective Analysis

All MRI training referrals between January 2014 and October 2018 were retrospectively investigated for training effectiveness and underlying medical, neuropsychological or sociodemographic moderators of MRI success. An MRI training was defined as successful when patients could lie still for a minimum of one MRI sequence. An MRI scan was defined as successful when it yielded interpretable results (with none to moderate movement artifacts), defined by a neuroradiologist and did not require the use of sedation/anesthesia. Quality of MRI pictures was rated on a three-point scale (no or mild motion artifacts; moderate motion artifacts; severe motion artifacts or termination). As part of the standard of care protocol at the neuro-oncology unit, all patients were administered a comprehensive neuropsychological test battery before or after the MRI training. For this retrospective study the different pre-existing neuropsychological test results relevant for the study question were included in the analysis. Details on the neuropsychological tests administered can be found in table 2 [40-49].

Table 2: Neuropsychological tests

Neuropsychological construct	Name of test	Year	Citation
Intelligence	Wechsler Intelligence Scale for Children - Forth Edition	2011	[36]
	Wechsler Preschool and Primary Scale of Inteligence – Third Editon	2014	[37]
	Adaptives Intelligenzdiagnostikum III	2014	[38]
	Bayley Scales of Infant and Toddler Development-Third Edition	2015	[39]
Attention	Kinderversion der Testbatterie zur Aufmerksamkeitsprüfung (KITAP)		[40]
	Konzentrations-Handlungsverfahren für Vorschulkinder	2006	[41]
Memory	Verbaler Lern- und Merkfähigkeits Test	2001	[42]
	Wiener Entwicklungstest	2012	[43]
	Developmental Scoring System for the Rey Osterrith Complex Figure		[44]
Behavior	Strengths and Difficulties Questionnaire	1999	[45]

2.3.2 Prospective Analysis

The evaluation of patients’ emotional well-being was carried out using an array of images representing emotional states [50]. The children participating were asked to choose three of the presented images, which best describe their emotional well-being throughout the MRI training. For a more detailed evaluation and analysis of patients’ feelings in relation to the MRI procedure, an array of 18 different emotional displays categorized in positive, neutral, and negative was used. The evaluation of emotional well-being was conducted longitudinally over five different time points, before and after session one, before and after session 2 and after the diagnostic MRI.

The evaluation of the degree of confidence and knowledge of the children and their parents was carried out by medical staff in the radiology department during the diagnostic MRI scan. Due to procedural constraints, data were only available for children that completed their MRI without general anesthesia. Medical staff scored each category (child well-informed, child secure, accompanying person well-informed, accompanying person secure) on a scale from 1 to 10.

2.3.3 Statistical analysis

For data analysis a combination of descriptive statistics and statistical inference was used. The sample was described using common statistical indicators. If the level of measurement allowed for it, a Welch’s t-test was applied due to its robustness to unequal variances and sample sizes. This test generates non-discrete degrees of freedom [51]. Categorical variables were analyzed using Chi-squared-tests of independence. Where possible, measures of effect size were computed. In two-group comparisons, Cohen's *d* was calculated. For contingency tables with polytomous categorical variables, Cramér's *V* was calculated, whereby an odds ratio for 2x2 contingency tables was adopted.

The patients in this intervention reported their emotional state at five different points of time over the course of the study by selecting three faces out of a range of emotional displays. Subsequently, these emotions were categorized into positive, neutral, and negative emotions. Since the data was categorical and non-independent due to the longitudinal design, general linear model techniques were not applicable. Therefore, the change of selected emotions over the course of the intervention was analyzed using generalized linear mixed models (GLMM) with Poisson distribution and log link function. Maximum likelihood with Laplace approximation was used as an estimation method. These models are extensions of the general linear model which have been adapted to account for the categorical and dependent nature of the data [52].

A type I error rate of .05 was chosen in all analyses, thus tests that yielded probabilities below that level were considered statistically significant. No adjustments for type I error inflation were made; instead, effect sizes are reported (for a discussion, see [53]). In all analyses, the statistical programming environment R (version 3.60 for Mac OS) was applied; for GLMM analyses, the R package lme4 was used (version 1.1-24); graphics were created using the R package ggplot2.

3. Results

3.1 Effect of MRI training (Retrospective Analysis)

The principal goal of this intervention was to empower children and adolescents to manage undergoing MRI without the need for general anesthesia. The term *MRI success* will be used for MRI performance without general anesthesia. The overall success rate for the total sample of 105 patients was at 74%. The group that received the intervention (n=87) performed significantly better (81% success rate) compared to the group (n=17) that did not receive training (47% success rate; $\chi^2 = 9.1$, df = 1, p = 0.00). The odds ratio indicates that the chance of successfully managing MRI without anesthesia was almost five times as high in the group that received MRI training compared to the group that did not (*OR* = 4.92, 95 % *CI* = 1.64; 14.73, *p* = .00). Moreover, MRI picture quality was acceptable in the intervention group. See figure 2 for a visual comparison of MRI success rates per group.

3.2 Moderators of MRI success (Retrospective Analysis)

3.2.1 Sociodemographic and medical associations

There was no association between patients' sex and their probability of MRI success ($\chi^2 = 0.78$, $df = 1$, $p = .28$, $OR = 0.66$). Age ($t = 0.33$, $df = 47.18$, $p = .74$, Cohen's $d = 0.07$) and grade ($t = -1.06$, $df = 33.33$, $p = .30$, Cohen's $d = -0.21$) did not differ between patients that managed their scans without general anesthesia and those who required anesthesia. There was no significant association between the type of education and MRI success ($\chi^2 = 0.00$, $df = 1$, $p = .95$, $OR = 0.95$), i.e., the rate of need for sedation during scans did not vary between children in special education compared to patients in regular schools. Notably, patients' first language was not associated with MRI success, indicating that non-German native speakers did not have more difficulties compared to German native speakers ($\chi^2 = 0.02$, $df = 1$, $p = .90$, $OR = 1.06$).

MRI success rates in patients suffering from NF1 (without a brain tumor) were compared with patients suffering from a brain tumor; there was no significant association between the two variables ($\chi^2 = 1.84$, $df = 1$, $p = .17$, $OR = 1.9$). Furthermore, MRI success rates between different treatment options were categorized into four tiers: observance only, surgery only, surgery and chemo-, radio- or antiangiogenic therapy, chemo-, radio- or antiangiogenic therapy. Subsequent comparison showed no significant association between the treatment arm and MRI success ($\chi^2 = 3.62$, $df = 3$, $p = .30$, Cramér's $V = .19$).

However, the onset age of the diagnosed medical condition differed significantly between patients that managed MRI without anesthesia and those that required anesthesia ($t = -2.17$, $df = 56.69$, $p = .03$, Cohen's $d = -0.44$). Patients that required anesthesia exhibited a significantly lower mean age (2.21 vs. 3.1 years, respectively) at the onset of their medical conditions.

3.2.2 Neuropsychological and behavioral associations

The successful completion of their MRI scans without requiring general anesthesia could not be explained by IQ (as measured predominantly by Wechsler-tests [40-42]), attention (KiTAP [44]), or concentration (KHV-VK [45]). See table 3 for more detailed information on neuropsychological data. However, memory (VLMT [46] or WET [47]) showed a significant, medium effect size which is visualized in a boxplot in figure 3. Patients that needed anesthesia scored significantly lower in their memory tests (M = 25.91, SD = 22.44) compared to patients that did not need general anesthesia (M = 46.33, SD = 31.12).

Table 3: Neuropsychological differences in MRI success and relationships between MRI success and behavioral variables

	t (*df*)	*p*	Cohen's *d*	
IQ (Wechsler test)	0.06 (28.67)	.95	0.02	
IQ (AID-3)	-1.38 (13.67)	.19	-0.57	
Range of intelligence (AID-3)	0.18 (10.36)	.86	0.08	
Memory (VLMT/WET)	-3.03 (38.28)	.00*	-0.72	
KHV-VK: time	0.27 (23.12)	.79	0.09	
KHV-VK: errors	-0.71 (23.34)	.48	-0.25	
KiTAP: time in distractibility condition	0.37 (21.18)	.72	0.11	
KiTAP: correctness (distractibility condition)	-0.10 (13.08)	.92	-.04	
KiTAP: completeness (distractibility condition)	-0.94 (21.06)	.36	-.29	
SDQ category (normal vs. critical range)	**χ^2 (*df*)**	***p***	**Odds ratio**	**Cramér's *V***
Overall stress	2.57 (1)	.11	2.37	.19
Emotional distress	0.42 (1)	.52	1.44	.08
Behavioral difficulties	0.74 (1)	.39	1.59	.10
Hyperactivity and attentional difficulties	8.31 (1)	.00*	4.73*	.34
Difficulties getting along with others	0.00 (1)	.97	1.02	.00
Kind and helpful behavior	1.52 (1)	.22	2.11	.14

*) significant at $p < 0.05$

To test for associations between MRI success and behavioral or emotional symptoms (SDQ) [49], the scores were dichotomized into the categories *normal* and *critical range*. The only category that showed a significant association with MRI success was *hyperactivity and attentional difficulties*. 48 percent of patients that required anesthesia during MRI exhibited high or very high levels of hyperactivity and attentional difficulties whereas only 19 percent of patients that did not require anesthesia exhibited high or very high levels (table 3.).

3.3 Evaluation of patients' emotional well-being (Prospective Analysis)

While in Study 1 the focus was on the effectiveness of the MRI training program and various variables associated with MRI success, in Study 2 the focus was on patients' emotional state. Participants were asked to report their current emotional state at five points in time over the course of the intervention by choosing 3 out of 18 emotional displays to best describe their emotional state. The emotional displays were categorized into positive, neutral, and negative emotions. Figure 4. shows the frequency at which patients selected each category over the course of the study. Separate GLMM's were applied for positive, neutral, and negative emotions. The point of time was included as a fixed-effect variable, while participant ID was included as a random-effect variable to account for the dependent data structure. Negative emotions dropped significantly (*beta* = -0.41, *z* = -3.64, *p* = .00, $R^2_{marginal}$ = .12), indicating a reduction of 0.41 in the count of negative emotions reported by participants with every point of measurement over the course of the study. Meanwhile, positive emotions were selected more frequently (*beta* = 0.27, *z* = -2.68, *p* = .00, $R^2_{marginal}$ = .14), indicating that participants reported 0.27 positive emotions more with every point of measurement. Neutral emotions showed a moderate decline which did not reach statistical significance (*beta* = -0.11, *z* = -1.38, *p* = .17, $R^2_{marginal}$ = .02). In these models, $R^2_{marginal}$ signifies the amount of variance explained by change over the course of the intervention.

3.4 Interdisciplinary evaluation (Prospective Analysis)

All categories evaluated by the medical staff exhibited median values above “8” on an visual analog scale (0-10), indicating generally favorable values. “Child secure” exhibited the lowest median as well as the largest variance (M = 8.74, SD = 1.34), with an overall high information level (“child well-informed” M = 9.25, SD = 0.73) The highest medians and the smallest variances were found in the categories concerning the accompanying persons, “Accompanying person well-informed/secure” (M = 9.42/9.42, SD = 0.51/0.52).

4. Discussion

The data collected supports the effectiveness of the evaluated MRI training program in preparing children for diagnostic MRI scans. Children who received prior training have a five times higher chance to have a successful diagnostic MRI scan than children who did not receive a training. Furthermore, 81.4% of children who received the MRI training managed the diagnostic MRI scan with good image quality, while children who did not receive a training had a chance of only 47%. Considering the high burden of disease and the great frequency at which childhood cancer patients have to undergo investigations, this chance of reducing the number of interventions and sedations could help reduce psychological and physical stress in patients and their families.

The success rate is similar to success rates in children with developmental delay and ADHD [9] but slightly lower than in prior studies with different patient populations [e.g. 8,21,25,30,32], but. The lower success rates in children who suffer from brain tumors or neurofibromatosis compared to other patient groups could be explained by the high mental stress families face when checking for treatment success or possible tumor recurrence, as well as cognitive issues often faced in these patient groups [10–13]. Another possible explanation could address differences in the duration of MRI scans among the study samples [9] ranging from 7 [24] up to 100 minutes [32]. Hence, randomized control trials need to be carried out to enable a more valid and well-founded judgement of the benefits of this novel program. Since the overall image quality was judged to be satisfactory in the entire group, it appears that for the future, image quality alone will not be the essential outcome criterion for the successful completion of an MRI training. From a clinical perspective, it seems even more significant to focus on the experienced well-being as well as the level of information as outcome criterion. Especially, since both contribute significantly to higher compliance and even more to a resilient outcome in life-long disease management [7, 28, 32, 34, 54].

Only a small number of studies have investigated the mechanisms underlying successful MRI scans in children showing associations with cognitive and language skills, [31] as well as age [25], temperament [9] patients' knowledge of the procedure, and previous medical experience [9]. Interestingly in the present study neither age, gender, treatment arm, nor the mother tongue had an influence on success rates. However, neuropsychological risk factors for MRI success are low scores in long-term memory, as well as reported attentional problems, two cognitive impairments that pediatric brain tumor and NF1 patients are especially vulnerable for [55]. Moreover, difficulties regarding memory and attention are often related to genetic components and early disease onset [56–57], which in turn was associated with a reduced MRI success rate. This is clinically plausible, since, for example, memory deficits do not only make it more difficult to remember the content of the training and particularly strategies, to lie still and to cope with stressful situations, but can also lead to an increased feeling of insecurity, which might be multiplied in stress evoking situations such as MRI scans [61]. Overall, the neuropsychological moderators clearly show that it is important to customize the training according to the patient´s neuropsychological outcome and developmental stage, which in turn needs highly specialized and well-trained psychological staff. Further research is necessary to evaluate if prior memory or attentional training leads to an even higher success rate.

The value of integrating the parents' perspective is further underlined by the fact that only attentional difficulties based on the external observation from the parents modified MRI success while results in tests on attention and concentration did not. However, this might be due to the nature of the tests chosen to check for attentional difficulties. In addition to the evaluation of focused attention (KHV-VK and KITAP-distractibility condition), future studies should include an assessment of other dimensions of attention as well as record the exact duration of the individuals' sessions to allow for an investigation of a possible relationship between intervention time and the program's effectiveness, to derive practical implications for clinical assessment.

Compared to other MRI training tools, the major difference of the present approach lies in the integration of role play techniques as well as in vitro training, two learning strategies that are especially effective for elaborating and solidifying the training content [23, 28, 58]. In a preventive sense, strategies considering emotional outcome (e.g. reduction and/or avoidance of fears) are implemented at an early stage to ensure short-term and long-term follow-up care [16, 33, 54]. The results emphasize the importance of the training being performed by clinical psychologists specialized in child development and neuropsychology who closely work together with medical doctors and radiotechnology assistants in an integrated care system [36, 59–60]. In future it will be of great interest to adopt the assessment scale of the interdisciplinary report to get more detailed information of the performance during MRI to derive further practical implications for psychosocial support. Transferring the training methods into daily life can additionally help to solidify the learned content, which was supported in the evaluated program by the parents acting as co-therapists. Additionally, to the aim of increasing immediate treatment success, the close interaction with and evaluation of the patients by this comprehensive team, can also enables the professionals to better judge whether patients are prepared to undergo MRI examinations without sedation. In turn, the risk of stress and trauma can be reduced [9, 17]. Hence, the present study was the first to show that children experience a variety of emotions with regards to an MRI, which might change over time. While prior work has exclusively focused on fear, anxiety, and distress [7, 31, 33, 37, 38] the use of an array of 18 different emotional displays categorized in positive, neutral, and negative, allowed for a more detailed evaluation of patients' feelings in relation to the MRI procedure. The results illustrate a high variability of emotional experience and highlight positive emotions associated in dealing with an MRI examination. Tracking the emotional state over of 5 time points, a decrease in negative and an increase in positive emotions was evident, reaching their peak after the completion of the diagnostic MRI, which might be related to the relieve after the completion of the diagnostic procedure. The changes in emotional wellbeing (first a reduction of positive emotions and only with continuation of the training an increase), illustrate the shifting process in the therapeutic procedure: information transfer (disengage - reduction of positive emotions) - learning new strategies in dealing (shift - reduction of positive emotions) - integration into everyday life (engage - stabilization or increase of positive emotions) [17]. The results highlight that the simple information is not sufficient. Moreover, standing alone without a follow-up appointment offering coping strategies can thus have the opposite effect and increase uncertainty.

5. Limitations

Although the small number of patients included in study 2 is a limiting factor, the results suggest that the administered MRI training can have benefits on the patients' psychological well-being, which is especially interesting because the program is designed for transfer into daily life of children. The sustainability of stress relieving strategies and coping mechanisms promoted through MRI training is an interesting field for further research. We would expect, among other things, that children with NF1 actually need more support in preparation, even though this has not been shown in the data. A differentiated evaluation with respect to disease and tumor entities is particularly desirable in order to be able to make more specific statements for selected risk groups.

6. Conclusion

The MRI Training "iMReady" is a highly feasible, evidence-based tool, which can easily be adjusted to the special needs of the heterogenous patient group in pediatric neurooncology. The results of the present study show that treatment compliance is moderated by disease-related cognitive, physical, and behavioral difficulties and that tailored trainings are effective in counteracting compliance problems and in increasing MRI performance. Furthermore, it was the first study to evaluate patients' emotional experience related to MRI procedures indicating a significant improvement in patients' self-reported emotional well-being throughout the psychoeducational program. Further studies with larger sample sizes as well as a randomly assigned control group are necessary to more thoroughly investigate the most relevant patient characteristics predicting successful treatment to allow for the trainings to be tailored to each individuals' needs. In addition, to ensure implementation and not compete with training time slots (20–30 minutes) to actual MRI examinations (increased waiting time), it would be beneficial if the MRI companies would build dummy machines to perform the training there.

Abbreviations

Magnetic resonance imaging	MRI
general anesthesia	GA
attention deficit hyperactivity disorder	ADHD
autism spectrum disorders	ADS
Intelligence quotient	IQ
Odds Ratio	OR
Standard deviation	Sd
generalized linear mixed models	GLMM
Wechsler Intelligence Scale for Children - Forth Edition	WISC-IV
Wechsler Preschool and Primary Scale of Inteligence – Third Editon	WPPSI-III
Adaptives Intelligenzdiagnostikum III	AID-3
Kinderversion der Testbatterie zur Aufmerksamkeitsprüfung	KITAP
Konzentrations-Handlungsverfahren für Vorschulkinder	KHV-VK
Verbaler Lern- und Merkfähigkeits Test	VLMT
Wiener Entwicklungstest	WET
Strengths and Difficulties Questionnaire	SDQ
Österreichische Gesellschaft für Hämatologie & Medizinische Onkologie	OeGHO

Declarations

Ethics approval and consent to participate

This study was performed in line with the principles of the Declaration of Helsinki. Approval was granted by the Ethics Committee “Ethik Kommission Wien” (EK Nr: 1564/2017). Where applicable, informed consent was obtained from the participants´ legal guardians.

Availability of data and materials

The datasets generated and/or analyzed during the current study are available from the corresponding author on reasonable request.

Competing interests

The authors declare that they have no competing interests.

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Authors' contributions

LJWW conceptualized and designed the project, performed the interpretation of data, and drafted the work. JF performed the acquisition, analysis, and interpretation of data, and contributed to drafting the work. VFF contributed to the conception and design of the work. AS contributed to the conception and design of the work, as well as the acquisition, analysis, and interpretation of data. AEH contributed to the acquisition, analysis, and interpretation of data, as well as drafting the work. TP contributed to the interpretation of data; revised the article substantively. JFS contributed to the acquisition, analysis, and interpretation of data, and revised the draft substantively. DP, IS, AP, and AA contributed to the conception of the work, the interpretation of data, and revised the draft substantively. PB assisted in the design of the work and the acquisition of data. UL contributed to the conception and design of the work as well as the interpretation of data; drafted the work and revised it substantively. All authors approved the submitted version and agreed to contributions.

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Figures

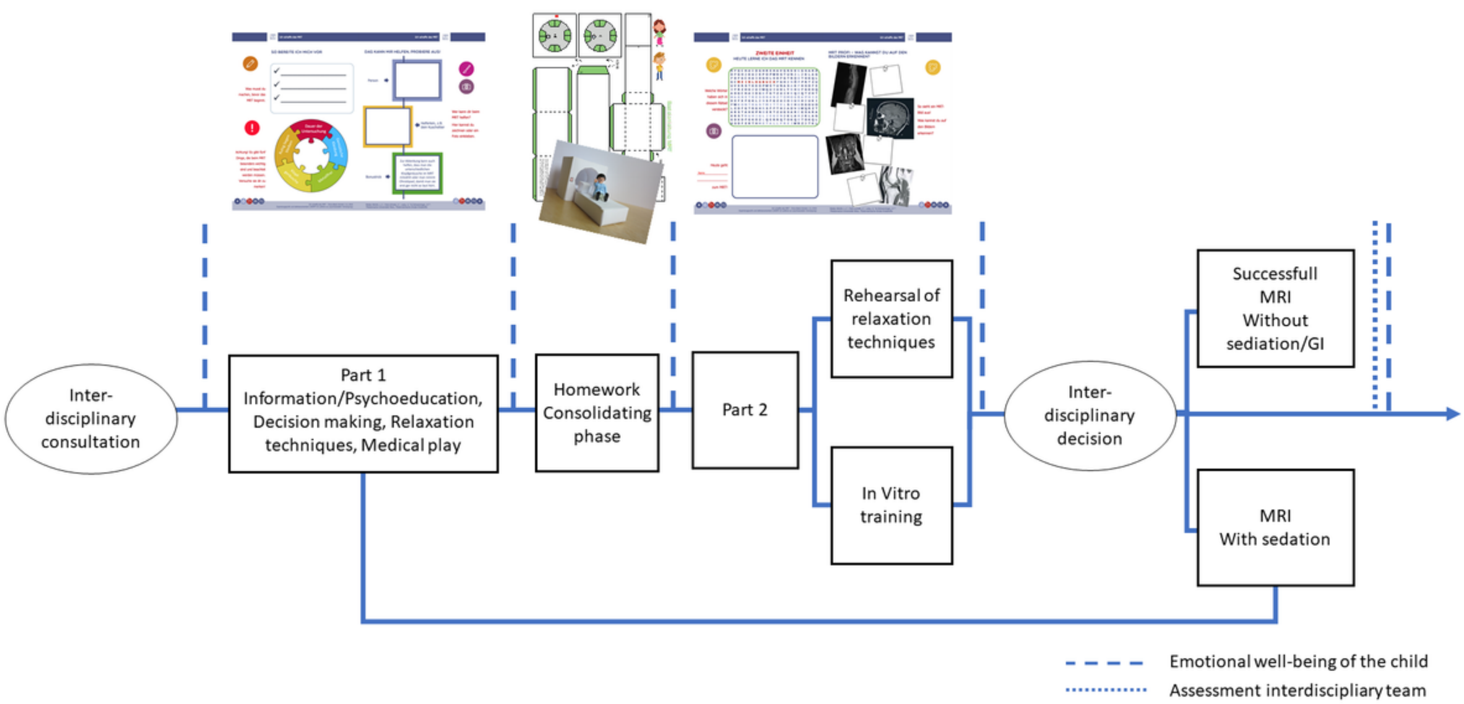

Figure 1

“iMReady” Workflow

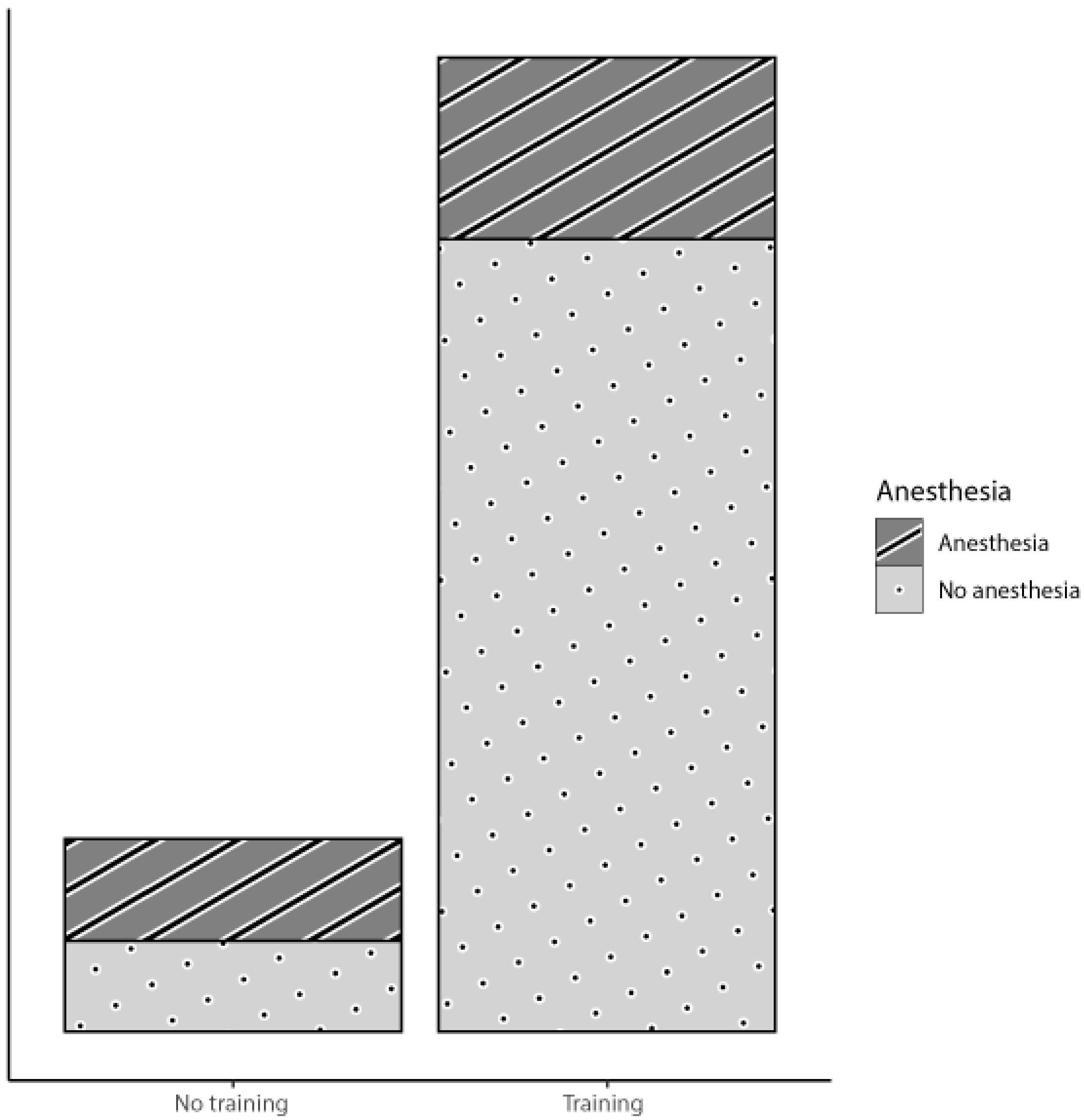

Figure 2

Stacked barplot for MRI success rates in both the intervention and the non-intervention group.

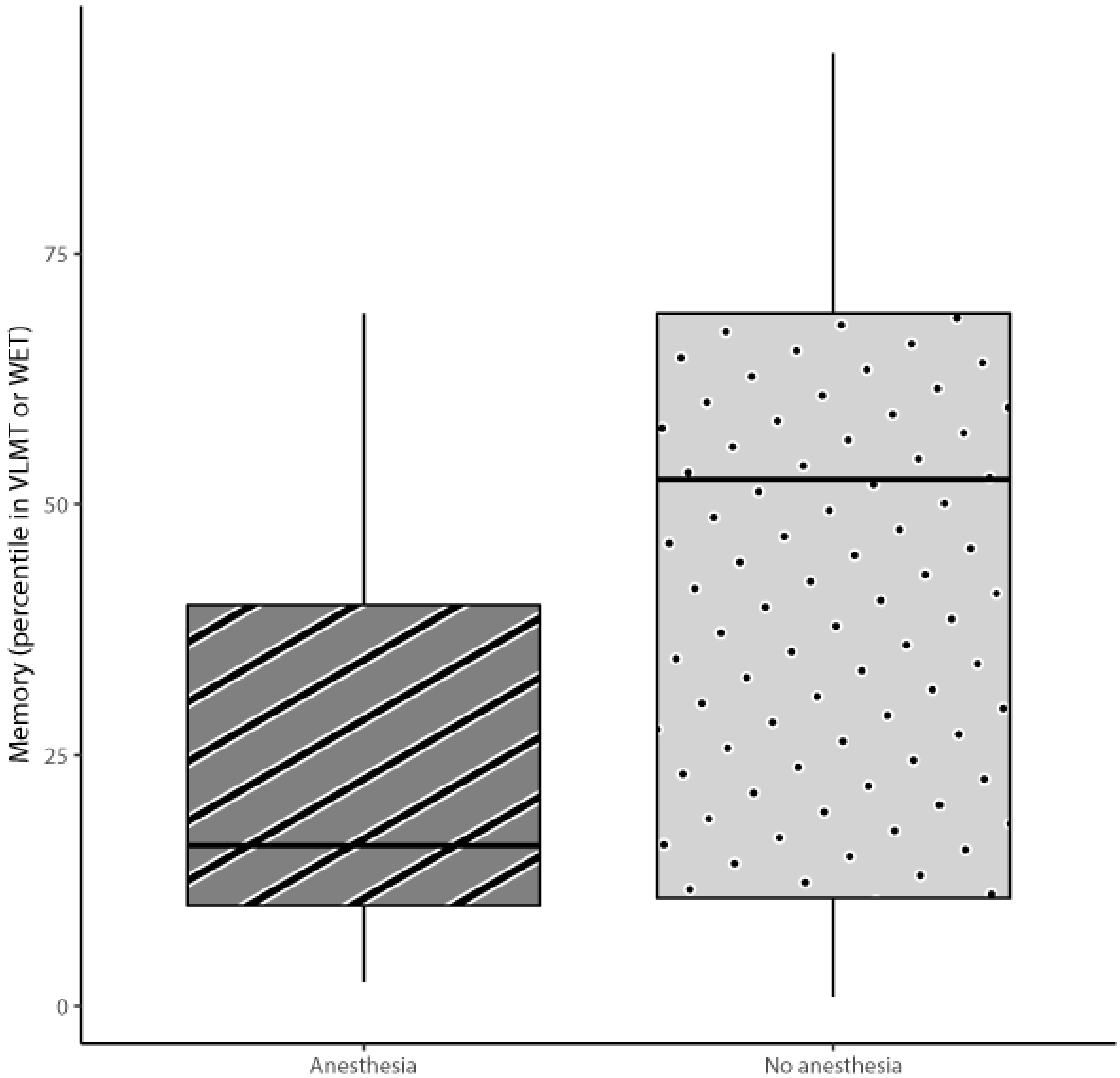

Figure 3

Boxplot of patients’ memory, as measured by VLMT or WET, compared by MRI success

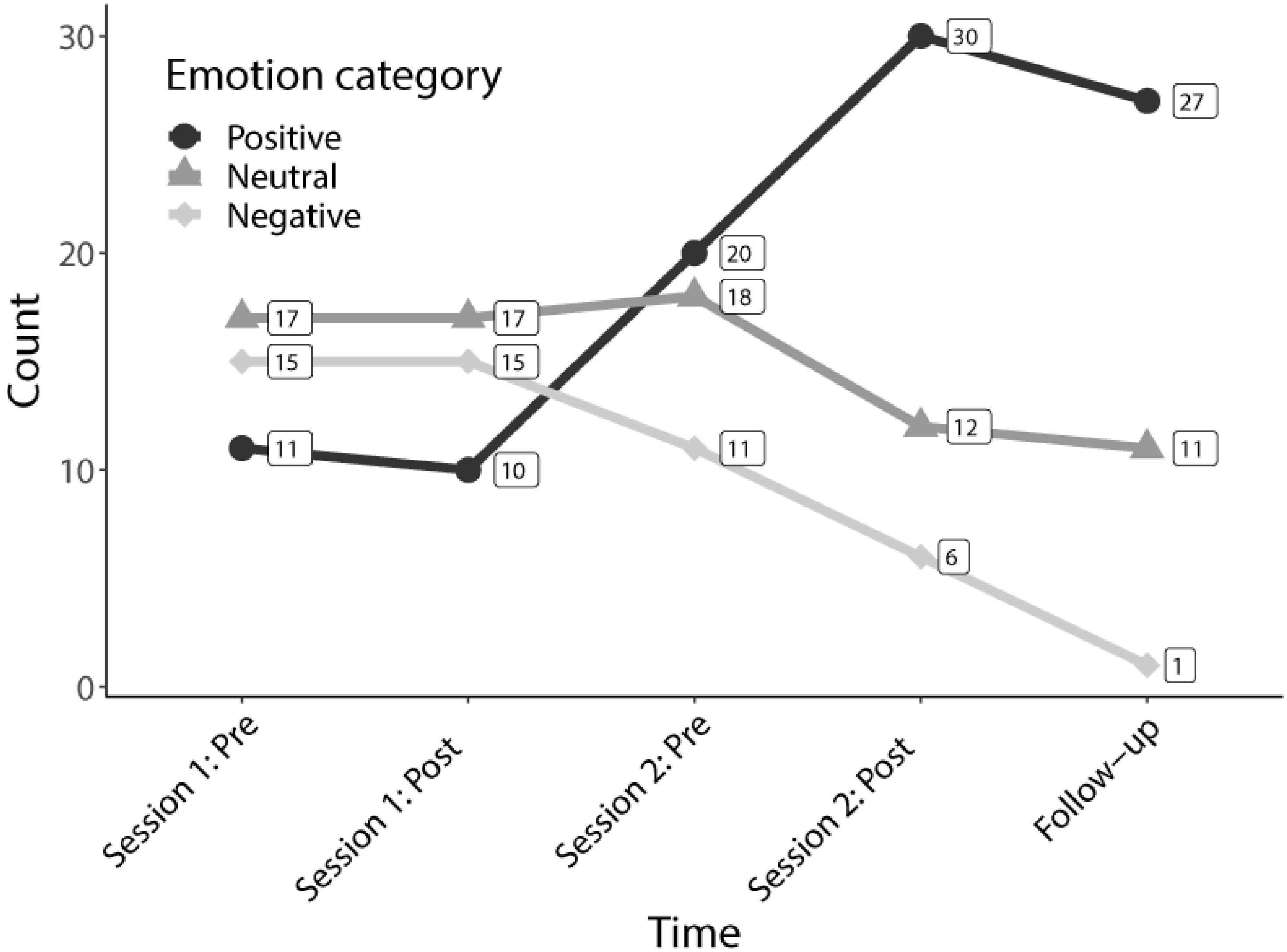

Figure 4

Line plot of frequencies of selected emotions over time.

Labels correspond to frequencies for the respective emotions at each time of measurement.