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1 The benefits of experiencing flow through distracting activities:

2 Flow reduces preoperative anxiety in children before surgery,

3 but not postoperative difficulties

4

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16 **Ethical considerations**

17 The ethical committee of Rennes Hospital approved this study (n° 19.59). The informed written

18 consent of parents and the verbal assent of each child were obtained prior to data collection.

19 **Disclosure statement**

20 The authors report there are no competing interests to declare.

21 **Data availability**

22 The data are available from the authors upon request.

23 **Preregistration**

24 This study was preregistered on Clinical Trials. Identifier : NCT04079244.

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3

4

Abstract

5 Distraction is a classic anxiety management strategy in preoperative setting with
6 children: distracting activities take children's attention away from threatening clues. What is
7 less clear is the differential effectiveness of this technique depending on the task, and the degree
8 of children engagement with the distracting task. The present work examined the role of flow
9 (state of intense concentration and absorption in the distracting task) on children's preoperative
10 anxiety. Anxiety and flow in a distracting activity were measured in a sample of 100 children
11 (3 to 10 years-old), at two critical moments of the preoperative period prior to ambulatory
12 surgery under general anesthesia (phase 1: up to separation from the parents; phase 2: up to
13 general anesthesia). Common negative postoperative outcomes were also measured. As
14 expected, the analysis showed a negative association between the mean level of flow in the
15 distracting activity during waiting periods and the preoperative anxiety of children at critical
16 moments in the two phases (although there was no effect on postoperative recovery). These
17 findings demonstrate the importance of considering the degree of engagement in the distracting
18 activity to understand the effectiveness of this strategy. The results may help provide guidance
19 for better clinical application of this method.

20

21

Keywords

22 Preoperative anxiety; Flow; Technological distraction; Children; Postoperative recovery

1 Distracting activities can be used as a coping strategy (Lazarus & Folkman, 1984), in
2 that they aim to reduce distressing emotions (e.g., Rankin et al., 2018). This strategy diverts
3 attention from the stressful event to more enjoyable situation (Gross, 2014), which reduces
4 distress (Compas & Boyer, 2001; Traeger, 2013). Two meta-analyses (Augustine &
5 Hemenover, 2009; Webb et al., 2012) investigated the efficacy of emotion regulation strategies
6 and identified that distraction was an effective strategy. Of particular interest for applied
7 purposes, the use of distraction has been recognized as effective to regulate preoperative anxiety
8 in children (for a review see Koller & Goldman, 2012). By redirecting attentional resources,
9 children can be distracted from the stressing event, which can decrease anxiety without
10 employing a pharmacological intervention (e.g., midazolam).

11 However, there is a subjective difference between the experience of being just
12 temporarily distracted (like quickly touching a video game or flipping through a book) and
13 being completely cognitively engrossed (never stopping the activity to conquer the next level
14 or to complete the book). This difference has been overlooked by past literature, which has
15 often focused on "distraction" without further distinctions. In particular, the difference in the
16 effectiveness of these distraction strategies has not yet been studied in the area of preoperative
17 anxiety. This is an important topic in applied settings, given that a deeper understanding of
18 distractors could help identify the right levers on which to play to improve efficacy of these
19 strategies - as called for by prior study (Chow et al., 2016).

20 The idea of degree of engagement in a (distracting) task has been particularly studied
21 through the concept of flow, which can be defined as a state of intense absorption in an activity
22 (Csikszentmihalyi, 1975). In the current study, we were interested in quantifying the extent to
23 which the experience of flow caused by a technological distraction affects preoperative anxiety
24 in children, as a window into the selection of the most effective distractors.

25

1 **Use of Distractions to Regulate Preoperative Anxiety**

2 Preoperative anxiety has a high prevalence: at least 36% of children (Rema et al., 2016)
3 develop preoperative anxiety during the waiting period before a surgery (and up to 65% in the
4 study of Kain et al., 1996). Two moments are particularly critical during the preoperative
5 period: separation from the parents (Banchs & Lerman, 2014), and undergoing anesthesia
6 (anesthesia induction) (Fortier et al., 2010). Preoperative anxiety is associated with multiple
7 posthospitalization behavioral changes (such as enuresis), occurring in about 67% of children
8 on the day after their surgery (Kain et al., 1999) and 24% on day 3 (Stargatt et al., 2006).
9 Children who are anxious during anesthesia induction also experience more emergence
10 delirium (Kain et al., 2004) and pain (Chieng et al., 2013) in the postoperative period.

11 Distraction is a strategy commonly used to regulate preoperative anxiety (Koller &
12 Goldman, 2012). Many studies have confirmed the effectiveness of this strategy: it can be
13 effective using technological distractions (e.g. Marechal et al., 2017; Patel et al., 2006; Seiden
14 et al., 2014; Stewart et al., 2018), various toys (Sahiner & Bal, 2016) or clowns (Golan et al.,
15 2009). Recently, a systematic review (Chow et al., 2016) showed a good effectiveness of
16 distraction in the regulation of preoperative anxiety (based on five studies testing this strategy).
17 These distracting activities take children's attention away from threatening clues and can thus
18 reduce their anxiety (Dahlquist et al., 2002). However, research on the field of preoperative
19 anxiety has been mostly restricted to comparing two experimental conditions: a distraction and
20 a control condition, often premedication with an anxiolytic (e.g. Marechal et al., 2017; Seiden
21 et al., 2014; Stewart et al., 2018). Although this approach is interesting, it does not allow for a
22 deep understanding of the mechanisms of distraction: for example, the lack of direct
23 comparison of different types of distractions limits insight into which distractions are more
24 effective to help regulate emotions, and why.

1 Based on the literature, there seems to be a role of attention in modifying emotional
2 outcomes, which could modulate the effectiveness of distraction in a preoperative setting.
3 According to the capacity model of attention (Kahneman, 1973), individuals have a limited
4 pool of attentional resources, which can be allocated on a specific activity or divided between
5 many activities. Besides, processing stressing events can also be considered as requiring
6 attention. For this reason, there can be a role of attentional allocation in emotional regulation:
7 the less attentional resources left available by a concurrent activity, the less resources to devote
8 to the anxiety-inducing situation (Wadlinger & Isaacowitz, 2011). When attentional resources
9 are captured by a distraction, there are no resources available for other activities: this leaves
10 less resources to devote to negative stimuli and can thus alter the emotional impact of these
11 stimuli. Therefore, consumption of attentional resources should be effective in down-regulating
12 negative emotions.

13 This idea suggests that if the effectiveness of distraction is created by the focus of
14 attention on another target, then there should be a difference in the effectiveness of distraction
15 strategies depending on the degree of allocation of attentional resources to the distracting task.
16 For example, one study (Van Dillen & Koole, 2007) examined the effect of working memory
17 demands of a distracting task in the attenuation of the negative emotions, and found that subjects
18 reported less negative emotions after a complex problem (high working memory load, i.e.
19 intense use of attentional resources) than after a simple problem (low working memory load).
20 This example supports the notion that people who focus their attention on an activity during a
21 stressful situation should better regulate their negative emotions.

22 In the specific context of preoperative anxiety, one study (MacLaren & Cohen, 2005)
23 examined the impact of children's engagement in a distracting activity (computer games or
24 movies) on feelings of distress during a venipuncture. The results indicated that children who
25 were the most engaged (indexed by the time spent on the distracting activity) were also the least

1 distressed, supporting the notion that the intensity of attentional resources allocation to the
2 distracting activity can moderate the effectiveness of the regulation of preoperative anxiety.

3 Things may not be as simple as having children perform the most attentionally-
4 demanding task available, however. Another study (Bowman & Tamborini, 2012) evaluated
5 the effect of different task demands (using different levels of difficulty in computer games) on
6 the individual's ability to relieve stress. The study found a curvilinear pattern: increasing task
7 demands increased mood until they became too demanding, and then became detrimental. This
8 result confirms that a distracting activity that is too easy or not very demanding of attentional
9 resources will not result in effective regulation of anxiety, but it also suggests that the degree
10 of engagement in an activity depends on more than its difficulty and attentional requirements.
11 Understanding the mechanisms of engagement is thus essential in order to better understand
12 the effectiveness of distraction as a coping strategy. The mechanisms of engagement and
13 complete absorption in a task have been mostly described in the context of the flow theory
14 (Csikszentmihalyi, 1975).

15 **Being 'in the Flow' as a Lever of Effective Emotional Regulation**

16 Flow is a state in which people are deeply engaged and absorbed in an activity
17 (Csikszentmihalyi, 1975, 1997, 2009; Nakamura & Csikszentmihalyi, 2014). According to
18 Csikszentmihalyi's theory, a flow state is composed of three antecedents which are key
19 conditions necessary for a flow episode to occur: (i) clear goals, which provide an objective to
20 follow and permit to (re)focus attention on the task; (ii) relevant feedbacks to inform about the
21 completion of objectives and to adapt task performance if needed; and (iii) a perception of
22 balance between one's skills and the challenge (the task demands) (Rheinberg & Vollmeyer,
23 2003), which has to be above boredom (challenge<skills) and below anxiety (challenge>skills),
24 right on one's zone of proximal competence.

1 Six other components of flow are considered as aspects of the flow state itself: (iv) the
2 sense of time is distorted; (v) the person feels in control of his or her actions and the
3 environment; (vi) self-consciousness disappears; (vii) merging of action and awareness, in the
4 sense that the subject does not feel separated from what they are currently doing; (viii) intense
5 concentration on the task, with the person being completely focused on the task and investing
6 all their attentional resources in the activity; and (ix) the activity becomes an autotelic
7 experience, pleasurable and performed for its own sake.

8 Focused attention on the activity is thus a cognitive characteristic of flow, and plays a
9 central role in initiating and maintaining this state (Nakamura & Csikszentmihalyi, 2014;
10 Weber et al., 2009). Several studies have focused on the mobilization of attentional resources
11 in activities inducing flow (de Sampaio Barros et al., 2018; Keller et al., 2011; Keller &
12 Blomann, 2008; Rheinberg & Vollmeyer, 2003), often in the context of studying the third
13 antecedent of a flow state: the balance between challenge and skills. Based on experimental
14 induction (manipulating attentional demands by varying the difficulty level of the activity), the
15 literature converges to show that participants report the highest flow scores under balance
16 conditions (de Sampaio Barros et al., 2018; Keller et al., 2011; Keller & Blomann, 2008;
17 Rheinberg & Vollmeyer, 2003). Related to the theory of limited attentional resources
18 (Kahneman, 1973), this important characteristic of the flow experience might drive differential
19 effectiveness of distraction activities to regulate anxiety: when a person's attention is fully
20 invested in an absorbing distracting task, there are no available resource to treat other stimuli,
21 but this only occurs when the task induces the appropriate level of engagement.

22 To date, only a few studies that have investigated the association between the degree of
23 absorption on the distracting activity and the effectiveness of this strategy. One study (Rankin
24 et al., 2018) has attempted to demonstrate a relationship between the flow state in a video game
25 during a stressful waiting period manipulated and the regulation of emotions. Researchers have

1 found that flow levels in the distracting activity were negatively linked with negative emotions
2 and positively with positive emotions, supporting the effectiveness of the distraction strategy
3 to regulate anxiety by inducing a flow state.

4 **Rationale for the current study**

5 In summary, past literature has suggested that distraction is an effective strategy to
6 regulate preoperative anxiety of children (e.g., Marechal et al., 2017; Stewart et al., 2018). The
7 mechanisms of distraction in this context are however poorly known, and need to be understood
8 better if we are to optimize interventions by selecting the most effective distracting activities
9 (see Chow et al., 2016). Distraction appears to work through the use of attentional resources
10 (e.g., Bowman & Tamborini, 2012), which themselves are related to engagement in the activity
11 as manifested in a flow state (e.g., de Sampaio Barros et al., 2018). Studying flow levels is thus
12 a promising window into understanding which distractions work best, and why.

13 Based on this previous research, the major objective of the study was thus to investigate
14 how the level of flow, as generated by a distracting activity, can influence preoperative anxiety
15 level. We expected children with high flow levels during the waiting period to be less anxious
16 at time of separation from the parents (Hypothesis 1a), and at the time of anesthesia induction
17 (Hypothesis 1b). A secondary objective was to examine the relationship between levels of
18 anxiety and flow in the preoperative period and postoperative consequences (delirium, pain,
19 behavior changes), which are common outcomes after operations in children (Fortier et al.,
20 2010; Kain et al., 2004). High levels of anxiety at the time of anesthesia induction have been
21 associated with more delirium, pain and behavioral changes after hospitalization (e.g., Chieng
22 et al., 2013; Stargatt et al., 2006). Therefore, we hypothesized that low flow levels in the
23 distracting activity, and by implication high anxiety levels at the time of anesthesia induction,
24 would be associated with more delirium and pain (Hypothesis 2a) and more behavior changes
25 (Hypothesis 2b).

1 We investigated these questions in a preoperative setting through collaboration with a
2 **university hospital**, where distraction of children with an electronic tablet is a usual practice
3 before surgery. The partner association "Little cuddly toys" designed available electronic
4 tablets with several applications, including the video game used here. Each child between 3 and
5 10 was offered a tablet for the waiting period up until anesthesia induction. Children could use
6 a video game or a cartoon as a distracting activity, which constituted two experimental
7 conditions in the present study. We expected that including these two conditions would increase
8 the variability of flow levels in our sample, possibly making it easier to find a relation between
9 flow and anxiety. Indeed, video games should elicit higher flow levels than cartoons, due to
10 being a flow inducing activity with ideal characteristics (e.g. interactive, clear goals and
11 feedback; Sherry, 2004).

12 The procedure was similar to previous research in the field of preoperative anxiety and
13 video game distractions (e.g. Marechal et al., 2017; Patel et al., 2006; Seiden et al., 2014;
14 Stewart et al., 2018), with an added focus on flow. Flow and anxiety were measured throughout
15 the preoperative period. The preoperative period itself was split into two phases for analysis:
16 Phase 1 examined the waiting period from the arrival of children in the unit to the separation
17 from parents, which marks the first critical moment of the preoperative period (Banchs &
18 Lerman, 2014). Phase 2 examined the waiting period from the arrival into the operating theatre
19 waiting room (a few minutes after the separation from parents) to the anesthesia induction,
20 which is the second and most critical moment of the preoperative period (Fortier et al., 2010).

1 **Method**

2 This study was preregistered on ClinicalTrials.gov (Identifiers NCT04079244) prior to
3 collecting any data. The preregistration outlines the research questions and the study design¹.

4 **Participants**

5 This study took place at the Rennes University Hospital (France), in the pediatric
6 ambulatory surgery unit. Eligible subjects were children between 3 and 10 years, undergoing
7 general anesthesia for ambulatory surgical procedure. A total of 100 children were included in
8 this study. A power analysis, conducted post-hoc (due to the lack of similar studies that could
9 provide an effect size for reference) with G*Power 3 (Faul et al., 2009) suggested that this
10 sample size was sufficient to detect small effect sizes with a .05 error level, achieving 80%
11 power for effect sizes of $d = 0.57$ or $r = .27$, and 95% power for effect sizes of $d = 0.73$ or
12 $r = .34$.

13 Children with developmental or psychiatric disorders which did not allow them to use
14 a tablet (as identified by the health care team), and children who were not native French
15 speakers with the risk of not understanding the distracting activities, were not eligible to
16 participate. The sample comprised 40 girls and 60 boys (average age = 6.28 years old,
17 $SD = 1.98$). A total of 48 children had a history of prior surgeries (for those with prior surgeries,
18 the average number was 2.44, $SD = 2.31$).

19 **Materials**

20 *Distracting Activities*

21 **Video game « *Le Héros C'est Toi!* » [You are the hero!]**. This game, produced by
22 Nijji in 2014, for the association “Les P’tits Doudous” is adapted to the different phases
23 followed by children during the preoperative process. This game was developed to offer the
24 child a specific game at each stage of his care (preparation, waiting time, passage into the

¹ Two minor deviations from the pre-registered analyses are presented in supplementary material: Table S1.

1 operating theatre, anesthesia induction). Several mini-games are proposed (with three levels of
2 difficulty): choosing avatars for the caregivers, reconstructing the waiting room in an object
3 recognition game, and a memory game using the avatars of caregivers.

4 **Cartoon.** « Ice Age » and « Ice Age: The meltdown » are cartoons produced by 20th
5 Century Fox in respectively 2002 and 2006. These are computer-animated films with positive
6 reviews from children. The first is 81 minutes long, and the second is 91 minutes long.

7 *Measurement of Preoperative Anxiety*

8 Preoperative anxiety was assessed with the most widely used observer-rated measure of
9 preoperative child anxiety: the modified-Yale Preoperative Anxiety Scale (Kain et al., 1995).
10 The mYPAS includes five dimensions: (i) activity, (ii) vocalizations, (iii) emotional
11 expressivity, (iv) state of apparent arousal, (v) use of parents. Total scores are comprised
12 between 23 and 100. The same rater provided scores for all children. As a check of reliability,
13 a second rater scored 35% of the protocols and inter-rater agreement was computed using the
14 intra-class correlation coefficient (two-way random-effects model for both absolute agreement
15 and consistency, computed using the psych package for R: Revelle, 2018). Total anxiety scores
16 showed excellent reliability (consistency = .85; absolute agreement = .84).

17 *Measurement of Flow*

18 The flow state in the distracting activity was evaluated with an observational grid
19 (Tordet et al., 2021): The Flow Observational Grid (FOG). The FOG includes three dimensions:
20 concentration, joy and frustration. Total scores are comprised between 0 and 100. The reliability
21 of total scores, computed as the inter-rater agreement using the same procedure as for anxiety,
22 was excellent (consistency = .84, absolute agreement = .83).

23 *Measurement of Postoperative Pain*

24 Postoperative pain was assessed with the Face, Legs, Activity, Cry, and Consolability
25 scale (FLACC: Merkel et al., 1997), in real-time by a caregiver when the child woke up from

1 anesthesia. Total scores are comprised between 0 (no pain) and 10 (the worst pain). This tool
2 is routinely used in clinical practice for pain assessment.

3 ***Measurement of Postoperative Emergence Delirium***

4 Postoperative emergence delirium (which comprises disturbances during the recovery
5 of general anesthesia, such as uncontrolled movements, hallucinations, or confusions) was
6 assessed with the Pediatric Anesthesia Emergence Delirium (PAED: Sikich & Lerman, 2004)
7 in real-time by a caregiver. Total scores are comprised between 0 and 20. This tool is also
8 routinely used in clinical practice to determine whether special care is required.

9 ***Measurement of Post-Hospitalization Behavior Changes***

10 Behavior changes after the surgery were assessed with the Post-Hospitalization
11 Behavior Questionnaire (Vernon et al., 1966), completed by the parents. The PHBQ includes
12 26-items questionnaire with six subscales (general anxiety, separation anxiety, aggression
13 toward authority, eating disturbance, apathy and sleep anxiety). The questionnaire uses Likert-
14 type scales: parents rate behavioral changes between 1 (*much less than before the surgery*) and
15 5 (*much more than before the surgery*). Adverse changes (scores of 4 and 5) were summed to
16 compute a total score.

17 **Procedure**

18 Upon arrival at the hospital, children and parents were informed of the protocol and
19 decided whether they agreed to participate (refusing did not affect access to distracting
20 activities). Parents received an information letter outlining the study's objectives, and provided
21 written informed consent for their child to participate and be recorded on video; oral assent was
22 systematically obtained from the children, in line with ethical guidelines (Declaration of
23 Helsinki: World Medical Association Declaration of Helsinki, 2013; see also Waligora et al.,
24 2014). After a visit of the healthcare team for routine procedures (checking the patient's file,
25 etc.) a camera (Canon Legria – mini-X) was installed on the children's stretcher and switched

1 on to allow for later scoring of observational measures. Children then received the tablet with
2 either the video game ($n = 50$) or the cartoon activity ($n = 50$). A randomization by week was
3 employed: a week devoted to inclusion in the video game condition, the following week to the
4 cartoon condition, etc. Children could use the tablet for the whole period of waiting time, until
5 the anesthesia induction. Children assigned to one distracting activity were not informed of the
6 existence of the other.

7 Phase 1 of the data collection focused on the waiting period between admission in the
8 ambulatory surgery unit to the separation from parents, when children were transferred to the
9 operating room. This phase lasted 82 minutes on average ($SD = 53$ minutes). Phase 2 focused
10 on the waiting period between transfer to the operating theatre waiting room (where many
11 patients wait before entering the operating room) and the anesthesia induction. This phase lasted
12 34 minutes on average ($SD = 21$ minutes). When the anesthesia team was ready, children were
13 admitted into the operating theatre where they were installed, prepared for surgery, and then
14 underwent anesthesia; data collection for Phase 2 stopped at this point.

15 After the surgery, children were transferred to the recovery room. Postoperative pain
16 and postoperative emergence delirium were assessed by the health care team at this point.
17 Children were transferred to the ambulatory surgery unit where their parent waited for them.
18 After an observational phase, they could leave and go back home. Postoperative behavioral
19 changes were assessed using the PHBQ, which was sent to the parents by e-mail and completed
20 three times: one day after the surgery, one week after the surgery, and one month after.

21 **Data Processing**

22 Anxiety and flow were scored based on the videotapes of children collected during their
23 waiting time. Because they could not feasibly be scored for the whole extent of waiting periods
24 lasting up to several hours, raters assessed both anxiety and flow at discrete intervals. Anxiety
25 levels were assessed at the beginning of the two phases (immediately before receiving the tablet

1 with distracting activities for Phase 1, and upon arrival in the operating theatre waiting room
2 for Phase 2) and at the two critical moments in the preoperative period (immediately before the
3 separation from parents for Phase 1, and immediately before anesthesia induction for Phase 2).
4 Flow in the distracting activity was assessed five times in both phases: two minutes after the
5 beginning of the waiting period, at 25% of the waiting time, at 50%, at 75% and two minutes
6 before the end of the waiting period. These five measurement points were averaged so as to
7 obtain mean flow levels for Phase 1 and Phase 2.

8 There were some missing data in both phases. Some were due to technical difficulties
9 related to the clinical setting, such as the video equipment turning off because of a low battery
10 or falling off the stretcher, children moving out of the camera's view, or children having their
11 face obscured behind the tablet ($n = 14$ for Phase 1 and $n = 21$ for Phase 2). For Phase 1, some
12 data were also missing due to a waiting time period too short to assess flow and anxiety levels,
13 or due to children not spending enough time on the distracting activity for a meaningful
14 assessment ($n = 16$). Only complete data were used ($N = 70$ for Phase 1 and $N = 79$ for Phase 2)
15 in analysis.

16

17

Results

18 Phase 1

19 *Preliminary analysis*

20 Descriptive statistics for anxiety and flow levels, for each distracting activity, are
21 presented in Table 1. On average, children reported significantly higher levels of anxiety at the
22 time of separation than upon arrival in the ambulatory unit, $t(69) = 3.85$, $p < .001$,
23 $d_z = 0.46$ (see Table 2), confirming that the preoperative setting constituted a stressful situation
24 for children.

1 Mean levels of flow differed as a function of the distracting activity, $t(68) = 3.52$,
 2 $p < .001$, $d = 0.85$: as expected, flow levels were higher for children using the video game than
 3 the cartoon (see Table 1). There were no significant differences for anxiety score at the time of
 4 separation from parents between children using the video game and for children using the
 5 cartoon, $t(68) = 0.13$, $p = .898$ (see Table 1). Correlations between all variables, as a function
 6 of distracting activity, are displayed in Table 2. The correlations among key study variables
 7 were all similar for the two conditions of distraction (the same correlations were significant in
 8 the same direction).

9
 10 **Table 1**

11 *Descriptive statistics for Phases 1 and 2*

| | Video game | | | Cartoon | | |
|------------------------------------|------------|-------|---------------|---------|-------|---------------|
| | Mean | SD | Range | Mean | SD | Range |
| Phase 1 | | | | | | |
| Anxiety at arrival | 31.20 | 10.01 | 23.30 - 68.30 | 32.40 | 8.56 | 23.30 - 60.00 |
| Anxiety at separation | 38.80 | 20.10 | 23.30 - 93.30 | 38.20 | 17.00 | 23.30 - 100 |
| Mean level of flow | 40.70 | 17.40 | 14.60 - 91.70 | 28.90 | 10.60 | 10.00 - 58.30 |
| Total waiting time (min) | 73.10 | 43.20 | 20 - 185 | 91.00 | 51.30 | 20 - 245 |
| Phase 2 | | | | | | |
| Anxiety at arrival in waiting room | 32.90 | 12.60 | 22.90 - 66.70 | 39.50 | 12.50 | 22.90 - 62.50 |
| Anxiety at anesthesia induction | 44.10 | 11.90 | 22.90 - 68.80 | 51.70 | 19.40 | 29.20 - 100 |
| Mean level of flow | 35.30 | 18.40 | 8.33 - 97.20 | 22.40 | 11.60 | 8.33 - 56.50 |
| Total waiting time (min) | 32.10 | 15.90 | 10.00 - 70.00 | 35.10 | 24.90 | 5 - 110 |

Note. For Phase 1, $n = 31$ for video game and $n = 39$ for cartoon. For Phase 2, $n = 40$ for video game and $n = 39$ for cartoon. Possible range of scores: anxiety: 23-100; flow: 0-100.

1 **Table 2**2 *Correlations among key study variables for Phase 1*

| | Cartoon | Anxiety at arrival | Anxiety at separation | Mean level of flow | Total waiting time |
|------------------------------|----------------|---------------------------|------------------------------|---------------------------|---------------------------|
| Video game | | | | | |
| Anxiety at arrival | | - | .60*** | -.26 | .07 |
| Anxiety at separation | | .64*** | - | -.34* | .17 |
| Mean level of flow | | -.20 | -.50** | - | -.14 |
| Total waiting time | | .09 | .19 | .22 | - |

Note. *** $p < .001$, ** $p < .01$, * $p < .05$. The correlations in the upper diagonal of the matrix are for the "cartoon" group ($n = 39$), the correlations in the lower diagonal are for the "video game" group ($n = 31$). All correlations were similar when using Spearman's correlation coefficient.

3

4 *Effect of flow in the distracting activity on anxiety at separation*

5 There was a negative correlation between anxiety at the moment of the separation from
6 parents and the mean flow level during the waiting period, $r(70) = -.39, p < .001$ (see Figure 1),
7 in line with our Hypothesis 1a. Replicating the analysis using the non-parametric Spearman
8 correlation to account for positive skewness of anxiety also yielded a significant negative
9 correlation, $\rho = -.54, p < .001$. The relation between flow and anxiety at separation was still
10 significant ($\beta = -.30, p = .005$) in a multiple regression controlling for possible covariates: total
11 waiting time (relation with anxiety at separation: $\beta = .21, p = .023$), anxiety level at arrival
12 (relation with anxiety at separation: $\beta = .56, p < .001$), the type of distracting activity (relation
13 with anxiety at separation: $\beta = .21, p = .031$) and the interaction between flow level and type of
14 distracting activity ($\beta = -.09, p = .354$). This regression model explained a large share of the
15 variance of anxiety levels at separation, $F(5, 64) = 13.71, p < .001, R^2 = .52$.

16 **Phase 2**17 *Preliminary analysis*

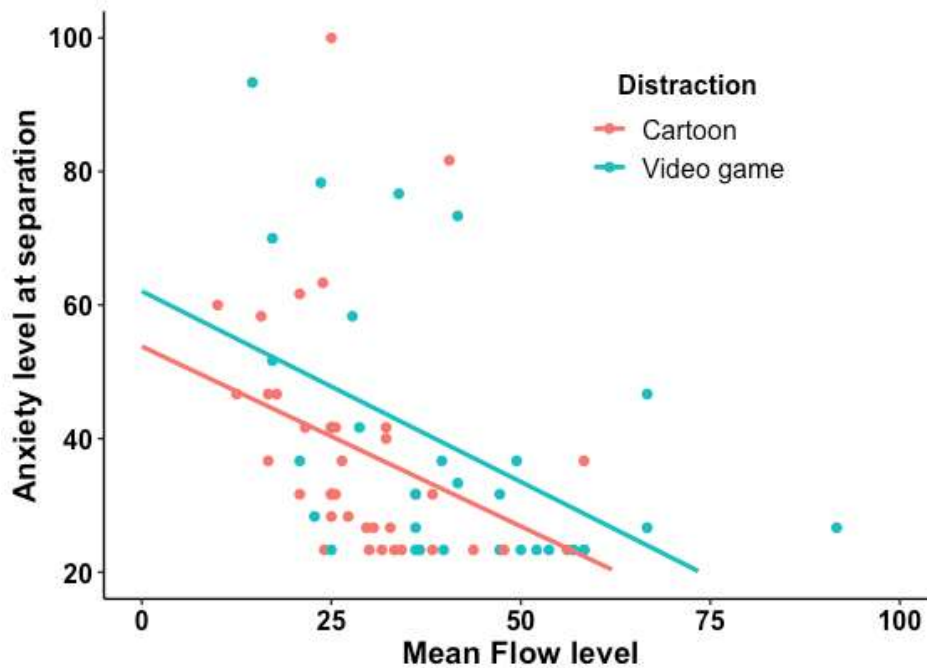
18 Descriptive statistics for anxiety and flow levels, for each distracting activity, are
19 presented in Table 1. On average, children reported significantly higher levels of anxiety at the
20 time of anesthesia induction than upon arrival in the waiting room, $t(78) = -6.71, p < .001$,

1 $dz = 0.76$ (see Table 1), confirming that this constituted a stressful situation for children. When
2 compared to Phase 1, anxiety was significantly higher at anesthesia induction than upon arrival
3 in the ambulatory unit, $t(77) = 8.71, p < .001, dz = 0.99$, and significantly lower at separation
4 from the parents than at anesthesia induction, $t(71) = 5.17, p < .001, dz = 0.61$. Anxiety was
5 significantly higher at arrival in the ambulatory unit than at arrival in the waiting room
6 $t(77) = 3.93, p < .001, dz = 0.44$, but did not significantly differ between arrival in the waiting
7 room and separation from the parents, $t(71) = 0.02, p = .987, dz = 0.00$. The mean level of flow
8 was significantly lower in Phase 2 than in Phase 1, $t(57) = 3.59, p < .001, dz = 0.47$.

9 As in Phase 1, mean levels of flow differed as a function of the distracting activity,
10 $t(77) = -3.74, p < .001, d = 0.84$: with higher flow levels for children using the video game than
11 the cartoon (see Table 1). Anxiety at the time of anesthesia induction was correspondingly
12 lower for children using the video game than for children using the cartoon, $t(77) = 2.11,$
13 $p = .038, d = 0.48$ (see Table 1). Correlations between all variables, as a function of distracting
14 activity, are displayed in Table 3, and were again similar for the two conditions of distraction.

1 **Figure 1**

2 *Association between mean level of flow and anxiety level at separation, for the two types of*
 3 *distracting activities*



4

5

6 **Table 3**

7 *Correlations among key study variables for Phase 2*

| Cartoon | Anxiety at arrival | Anxiety at anesthesia | Mean level of flow | Total waiting time |
|---|---------------------------|------------------------------|---------------------------|---------------------------|
| Video game | | | | |
| Anxiety at arrival in waiting room | - | .37* | -.72*** | -.14 |
| Anxiety at anesthesia induction | .56*** | - | -.49** | -.24 |
| Mean level of flow | -.62*** | -.32*** | - | .18 |
| Total waiting time | -.32* | -.22 | .09 | - |

Note. * $p < .05$. ** $p < .01$. *** $p < .001$. The correlations in the upper diagonal of the matrix are for the "cartoon" group ($n = 39$), the correlations in the lower diagonal are for the "video game" group ($n = 40$). All correlations were similar when using Spearman's correlation coefficient.

8

1 ***Effect of flow in the distracting activity on anxiety at anesthesia induction***

2 There was a negative correlation between anxiety at the moment of anesthesia induction
3 and the mean flow level during the waiting period, $r(79) = -.42, p < .001$ (see Figure 2), in line
4 with our Hypothesis 1b. Replicating the analysis using the non-parametric Spearman
5 correlation to account for positive skewness of anxiety also yielded a significant negative
6 correlation, $\rho(79) = -.48, p < .001$. The relation between flow and anxiety at separation was still
7 marginally significant, with an effect size identical to Phase 1 ($\beta = -.31, p = .056$), in a multiple
8 regression controlling for possible covariates: total waiting time (relation with anxiety at
9 anesthesia induction: $\beta = -.14, p = .166$), anxiety level at arrival (relation with anxiety at
10 anesthesia induction: $\beta = .24, p = .084$), the type of distracting activity (relation with anxiety:
11 $\beta = -.06, p = .587$) and the interaction between flow level and type of distracting activity
12 ($\beta = .22, p = .058$). This regression model explained a significant share of the variance of
13 anxiety levels at anesthesia induction, $F(5, 73) = 6.28, p < .001, R^2 = .30$.

1 Contrary to our expectations (Hypothesis 2a), no significant correlations were observed
2 between delirium and pain scores at awakening, and levels of anxiety at anesthesia induction
3 or mean levels of flow during the preoperative period (see Table 5). Levels of anxiety or flow
4 during the preoperative period did not appear to be related to pain and delirium levels during
5 the postoperative period. Likewise, there were no significant differences for pain scores
6 between children using the video game ($M = 1.38, SD = 2.49$) and for children using the cartoon
7 ($M = 1.08, SD = 2.32$), $t(77) = .54, p = .589$. There were no significant differences either for
8 emergence delirium children using the video game ($M = 1.25, SD = 3.92$) and for children using
9 the cartoon ($M = 1.85, SD = 4.77$), $t(77) = .61, p = .545$.

10 Concerning postoperative behavioral changes, the distributions of PHBQ scores were
11 also very positively skewed due to the majority of children not demonstrating behavioral
12 changes at all: no changes were reported for 50% of children one day after surgery, for 56%
13 seven days after surgery, and for 63% thirty days after surgery. There was no significant effect
14 of time on scores on the PHBQ, $F(2, 60) = 0.39, p = .678$, indicating that behavioral changes
15 were not affected by time elapsed since the operation on average. Contrary to our expectations
16 (Hypothesis 2b) no significant correlations were observed between the mean flow level during
17 the preoperative period or levels of anxiety at anesthesia induction and postoperative behavioral
18 changes at the three timepoints (see Table 5).

19 On average, postoperative behavioral changes one day after surgery were similar for
20 children using the video game ($M = 1.19, SD = 2.08$) and for children using the cartoon
21 ($M = 2.53, SD = 2.86$), $t(44) = 1.85, p = .072$. Welch's t -tests were used for the other two
22 timepoints due to unequal sample sizes and variances; they revealed lesser postoperative
23 changes for children using the video game ($M = 0.82, SD = 1.83$) than for children using the
24 cartoon ($M = 3.61, SD = 4.78$), $t(20.60) = 2.27, p = .034$. The same pattern appeared thirty days

1 after surgery, with lesser postoperative changes for children using the video game ($M = 0.19$,
 2 $SD = 0.56$) than for children using the cartoon ($M = 2.71$, $SD = 2.58$), $t(13.06) = 3.62$, $p = .003$.

3
 4

5 **Table 4**

6 *Descriptive statistics for postoperative measures*

| | <i>N</i> | <i>M</i> | <i>SD</i> |
|-----------------------|----------|----------|-----------|
| Pain | 78 | 1.23 | 2.40 |
| Delirium | 79 | 1.54 | 4.34 |
| PHBQ + 1 day | 46 | 1.74 | 2.49 |
| PHBQ + 7 days | 43 | 2.05 | 3.60 |
| PHBQ + 30 days | 41 | 1.05 | 1.96 |

Note. Possible range of scores: pain: 0-10; delirium: 0-20; PHBQ scores: 0-26.

7

8 **Table 5**

9 *Correlations among preoperative behaviors and postoperative consequences*

| Cartoon | Anxiety at induction | Flow level | Delirium | Pain | PHBQ +1 | PHBQ +7 | PHBQ +30 |
|-----------------------------|-----------------------------|-------------------|-----------------|-------------|----------------|----------------|-----------------|
| Video game | | | | | | | |
| Anxiety at induction | - | -.49** | .06 | .24 | -.26 | -.27 | -.40 |
| Flow level | -.32* | - | .22 | .13 | .05 | .07 | .05 |
| Delirium | -.10 | -.16 | - | .24 | -.23 | -.35 | -.41 |
| Pain | .07 | -.13 | .12 | - | .33 | .40 | -.47 |
| PHBQ +1 | -.01 | -.01 | .31 | .40* | - | .84*** | .57* |
| PHBQ +7 | -.07 | .01 | .09 | .32 | .88*** | - | .63* |
| PHBQ +30 | .08 | -.05 | .34 | .45* | .79*** | .75*** | - |

Note. * $p < .05$. ** $p < .01$. *** $p < .001$. The correlations in the upper diagonal of the matrix are for the "cartoon" group, the correlations in the lower diagonal are for the "video game" group. All correlations were similar when using Spearman's correlation coefficient.

10

1 **Discussion**

2 Distraction is an effective and recommended strategy to regulate preoperative anxiety
3 in children. To better understand the differential effectiveness of different types of distracting
4 activities, we investigated the effect of flow in a distracting activity on anxiety, for children at
5 two critical moments of the preoperative period: separation from parents and anesthesia
6 induction. We expected flow to provide an index of child engagement in the distracting
7 activities and to be related to decreased anxiety.

8 Overall, the results provided support for this hypothesis. In Phase 1, the results indicated
9 a strong negative link between flow and anxiety at the time of separation from parents, even
10 when controlling for other covariates. Children using a video game as a distraction
11 demonstrated higher flow but not lower anxiety at the time of separation from parents. In
12 Phase 2, there was also a strong negative link between flow and anxiety at the time of anesthesia
13 induction, and children using a video game demonstrated both higher flow and lower anxiety.
14 Although the effect of flow dropped to marginal significance ($p = .056$) in Phase 2 when
15 controlling for five other covariates, the effect size was in fact identical to Phase 1. Taken
16 together, these results suggest that a high level of flow is, indeed, related to lower levels of
17 anxiety, in line with our predictions (Hypotheses 1a and 1b).

18 These findings are in line with existing literature about the effectiveness of a distraction
19 strategy in preoperative context, in showing that being absorbed in a distracting activity can
20 help prevent high levels of preoperative anxiety during critical moments. Our study, however,
21 also provides an important complement to this literature. Prior studies testing distraction
22 strategies generally did not examine engagement in the distracting activity, simply considering
23 that once a distraction was delivered to children, they automatically used it (e.g. Lee et al.,
24 2013; Marechal et al., 2017; Patel et al., 2006). Our results illustrate that the degree of
25 absorption in the distracting activity is also an essential aspect to study and measure in order to

1 better understand the effectiveness of this strategy (also in line with the conclusions of
2 MacLaren & Cohen, 2005). In other words, providing a distraction is not sufficient to reduce
3 anxiety levels: engagement in the distracting activity also matters. Children have to be absorbed
4 in the distracting activity to gain an advantage in terms of anxiety regulation.

5 A major strength of the present study was that it was performed in an ecological context:
6 relations between flow state and anxiety level were directly examined in the preoperative
7 setting, and at the two most critical moments of the preoperative period. While offering less
8 controlled conditions than a laboratory study, this approach made it possible to investigate the
9 role of flow in a situation that is directly relevant to everyday clinical practice. Compared to
10 the traditional method of premedication, which may have undesirable side effects (Stewart et
11 al., 2018), distraction strategies are a non-intrusive alternative that healthcare professionals can
12 incorporate into their practice. This finding has significant implications for clinical practice, as
13 it suggests that healthcare professionals should consider the benefits of using distraction
14 strategies.

15 Regarding flow theory considered more broadly, our results also reflect those of Rankin
16 and colleagues (2018) who found that flow feelings were associated with lower negative
17 emotions during a stressful period. This study provides theoretical support for the idea of a
18 buffer effect of flow alleviating the feelings of anxiety during a stressful situation, due to
19 focused attention on the activity (Nakamura & Csikszentmihalyi, 2014; Weber et al., 2009)
20 absorbing limited attentional resources which can then no longer be devoted to the threatening
21 clues of the preoperative situation. An interesting feature of the results is that the relation
22 between the levels of flow and anxiety seemed to be bidirectional: in other words, both anxiety
23 and flow in the distracting activity may influence each other. In Phase 1, we observed that mean
24 flow levels during the waiting period were not affected by anxiety levels at the arrival in the
25 unit, whereas in Phase 2, children who arrived anxious in the waiting area showed weaker flow

1 levels on average. Part of the difference may be due to the fact that the anxiety levels of children
2 were moderate at their arrival in the hospital, and, their parents were present to help them to
3 disengage from the stressing situation and regulate their anxiety feelings – and perhaps to
4 encourage them to engage in the distracting activity. By contrast, after the separation from
5 parents, anxiety levels were higher on average and children had to regulate their anxiety on
6 their own.

7 Another important finding was that video game generates higher levels of flow than
8 cartoon, in both phases. This result was expected, video game meets the preconditions for the
9 flow state (i.e., clear goals and feedbacks: Sherry, 2004). This pattern appears to be reflected in
10 anxiety levels; while anxiety levels were similar at the time of separation between the two
11 conditions, anxiety levels differed at the time of anesthesia induction. Because the video game
12 is more demanding of attentional resources (therefore, eliciting more flow), this potentially
13 allows for greater attenuation of negative emotions. Future research should focus on comparing
14 various technological distractions to better understand their differential effectiveness.

15 **Effects of Flow and Anxiety on Postoperative Changes**

16 A secondary objective of the current study was to examine the influence of flow (and
17 the corresponding anxiety scores) during the preoperative period on postoperative recovery.
18 Contrary to our expectations (Hypotheses 2a and 2b), we failed to find significant differences
19 in postoperative measures (pain, agitation, behavioral changes) related to anxiety and flow
20 during the preoperative period. Some differences did appear between the cartoon and video
21 game distracting activities for postoperative behavioral changes one week and one month after
22 the operation, which could possibly be related to lower anxiety for children using the video
23 game. However, the lack of significant differences one day after the operation, and the low and
24 unbalanced sample sizes for this analysis make this result unreliable.

1 A likely explanation for this negative finding is that the postoperative measures had only
2 limited ranges, demonstrating floor effects. In other words, the adverse consequences of being
3 operated may have been generally too small to allow for the detection of variability related to
4 behavior in the preoperative period. Part of the reason may be that the scales we used, which
5 are used to identify children in need of special care post-operation, may not be sensitive enough
6 to discriminate between children with postoperative changes in the typical range. Another
7 possibility is the design of the current study: each child received a distracting activity to regulate
8 their anxiety, contrary to previous studies where children did not receive an intervention,
9 pharmacological or not, to help regulate their anxiety (Chieng et al., 2013; Kain et al., 1999,
10 2004), possibly limiting adverse postoperative consequences.

11 **Limitations and perspectives for future studies**

12 The present study raised several questions that could be explored in future protocols.
13 First, the use of a convenience sample due to the partnership with a child hospitalization unit
14 meant we had access to a restricted age range. Only children between 3 and 10 were included,
15 which means it would be beneficial to assess the effects of flow on anxiety in older children
16 and adults, for whom interactions with a distracting activity may be different.

17 In parallel, our sample did not permit investigation of developmental aspects, which
18 means children of all ages were considered together. This issue should be addressed in future
19 studies. Indeed, the developmental nature of coping is important to consider (Zimmer-Gembeck
20 & Skinner, 2011) and some developmental processes may be directly involved in the
21 effectiveness of distraction strategy. For example, the capacity of focused attention, which is
22 essential to support engagement in the distracting activity and therefore the flow state, depends
23 on the age of the child and is supported by the development of executive functions (for a review,
24 see Fisher & Kloos, 2016).

1 Another important point, partly related to the issue of development, is complexity of the
2 distracting activity. In the current study, some children may have failed to be completely
3 distracted because the activities' properties did not allow a high and long flow state. For the
4 video game, the complexity level of the mini-games may have been too easy for children used
5 to this media, or for the older children of the sample. Conversely, the cartoons may have been
6 ill-suited to the attentional control abilities of the younger children because of their long
7 durations. Further studies should incorporate more types of distracting activities so as to provide
8 an age and capacity-appropriate activity for each child: shorter and longer cartoons, video
9 games with more levels of difficulty or adaptive playing modes. This would presumably help
10 enhance flow in the activity for children of all levels and hence the effectiveness of distraction.

11 On a similar note, the results of Phase 2 showed weaker flow levels on average. Part of
12 the reason may be that the distractions available for the present study were not quite conducive
13 to maintaining a high flow state during a long period in all children. Young children may prefer
14 to switch between many activities rather than focusing on only one during a long time (Inal &
15 Cagiltay, 2007). The distractions available for this study did not permit children to alternate
16 freely between activities: the video game is a succession of mini-games, the last of which is
17 repeated until the anesthesia induction; the cartoons were long-duration feature films.
18 Distraction in Phase 2 may thus have been less beneficial due to the repetitive activity:
19 engagement on the distraction may be reduced because of the long time spent on it, as proposed
20 by Stewart and colleagues (2018).

21 Lastly, it would be worth investigating in more detail the use of distraction during the
22 waiting period and the role of parents. Likewise, further assessments could be undertaken to
23 explore the evolution of flow and anxiety levels during the waiting period, with more regularly-
24 spaced measures. Indeed, analyzing only select periods may come with unexpected effects: for
25 example, anxiety level as measured two minutes after arrival in the operating theatre may not

1 function quite like a baseline measure as expected (with this measure occurring a few minutes
2 after the separation from parents, some children could still be in a critical phase of anxiety).
3 This greater level of detail would be useful to better understand the mechanisms underlying the
4 relation between flow and anxiety and to provide guidance for clinical applications.

5 **Conclusion**

6 In conclusion, our results highlight the importance of engagement in distracting
7 activities used as a tool for regulating preoperative anxiety in children. The degree of absorption
8 in the activity appears to be a factor in reducing anxiety, and a video game appeared to be
9 associated with both higher flow and lower anxiety than a cartoon. In sum, it is desirable to
10 choose a distracting activity that will promote as much cognitive absorption as possible, and an
11 activity which engages the participant directly, such as a video game, may be more effective.

12 These findings contribute to the existing literature on the effectiveness of distraction
13 strategies, but the ecological context of the study also allows for an investigation of the role of
14 flow in a situation that is directly relevant to clinical practice. These findings therefore offer
15 insights for healthcare professionals, particularly those working with children who experience
16 high levels of preoperative anxiety. Although the study did not reveal significant differences in
17 postoperative measures as a function of anxiety and flow during the preoperative period,
18 minimizing anxiety in the preoperative period is already a very desirable outcome to maximize
19 patient well-being.

20 Further research is necessary to explore the potential of various technological
21 distractions for regulating preoperative anxiety in children, including how flow and anxiety
22 change over time during the activity, and to better understand the possibly bidirectional causal
23 relationship between flow and anxiety.

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