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Interventions promoting pro-environmental behaviors in children: A meta-analysis and a research agenda

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ABSTRACT

Adults resist change in their pro-environmental behaviors (PEBs); how can these behaviors be promoted in children? We reviewed studies that measure the effectiveness of interventions fostering PEBs in children. Sixty-five studies included a quantitative PEB measure and tested the effectiveness of an intervention (experimental manipulation comparing a treatment to a control group or testing its impact with a pre/post assessment), aimed at fostering PEBs in children. A meta-analysis of the 76 effects sizes revealed that interventions do increase PEBs among children (*Hedges' g* = 0.53). Interventions yielded greater effect sizes when actual and not self-reported behavior was measured, however the former are particularly scarce in the literature. We found evidence that intervention effectiveness decreases with children's age. A research agenda is proposed that calls for theoretical and methodological diversification, and the need to study actual and not only self-reported behavior, with interventions that start earlier in children's socialization processes.

In recent years, climate change and other human-induced environmental problems have led scholars to develop interventions aimed to influence human pro-environmental behaviors (PEBs) (Abrahamse & Steg, 2013; Bergquist et al., 2019; Nguyen-Van et al., 2021; Steg & Vlek, 2009; Wee et al., 2021). PEBs refer to either behaviors that omit to harm the environment (e.g., choosing multiple-use rather than single-use container) or to harm it in the least extent possible (e.g., using public transport instead of a private vehicle), or to those that benefit the environment (e.g., removing plastic garbage from water tanks) (Steg & Vlek, 2009). Such programs can be effective, but it is not clear whether such interventions produce long-lasting effects (Abrahamse et al., 2005; Nisa et al., 2019; Ro et al., 2017) and may sometimes produce rebound effects that paradoxically decrease PEBs after a while (Catlin & Wang, 2013). Nor is it guaranteed that such interventions are strong enough to compensate for factors that impede the behavioral change necessary to mitigate environmental issues at a global scale (Gifford, 2011; Swim et al., 2009). The motivation to reduce one's consumption is generally quite low (Steg, 2008), lower than the motivation to maintain a good level of comfort (Karlin et al., 2014), despite people's awareness of the problems of overconsumption (Sütterlin et al., 2013).

All these considerations conceal a crucial fact: they mostly apply to adults. Adults are the target population in the vast majority of studies, which reflects the obvious rationality of promoting PEBs in those who produce, consume, move the most, and have overall the highest potential to make an impact on the environment. Adults, however, are also less likely to change their behaviors than children. Among the sources of resistance to behavioral change, several are specific to adults. Habits and routines developed over the course of the years are difficult to alter (Kurz et al., 2015); firmly established ideologies of modern industrialized societies (e.g., continuous economic growth) clash with pro-environmental attitudes and behaviors (Heath & Gifford, 2006) and previous financial investments often interfere with the ecological transition (Gifford, 2011).

We argue that, since children are not affected by many of these obstacles, they might be particularly sensitive to interventions promoting PEBs. Children are the future stakeholders who will have to cope with a variety of increasingly pressing environmental issues, such as climate change, the loss of biodiversity and environmental pollution. Despite the

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urgent need for a review of factors that steer children's PEBs, no systematic review has presented to date a thorough account of interventions promoting PEBs specifically in children. Early research either conflated children's PEBs with those of adults (Zelezny, 1999) or was restricted to environmental education interventions that use knowledge transmission and raising awareness to achieve behavioral change (Neal & Palmer, 2003). More recently, van de Wetering et al. (2022) published a meta-analysis that also investigated the effectiveness of interventions promoting various outcomes, including children's PEBs. However, van de Wetering et al.'s meta-analysis included papers that considered children's PEBs at the household level, meaning that they were conflated with PEBs of adults (e.g., Barata et al., 2017; Craig & Allen, 2015; Thompson & Serna, 2016), failed to distinguish PEBs from behavioral intentions (e.g., Collado et al., 2013) and relied on studies where PEBs measurement had methodological pitfalls (e.g., Nuhoğlu & İmamoğlu, 2018). Crucially, this work was also restricted to environmental education interventions.

Social influence represents another potent leverage of behavioral change that occurs whenever a person's thoughts, feelings, or behaviors are influenced by other individuals or groups (Forgas & Williams, 2001, pp. 3–24). It has been successfully applied with many techniques such as social norms, feedback provision or social comparison to enhance PEBs in adults (Abrahamse & Steg, 2013; Bergquist et al., 2019; Cialdini, 2003). No such synthesis has assessed a similar endeavor in children. Likewise, no systematic review exists discussing other types of interventions that could meaningfully promote children's PEBs.

1. Scope of the meta-analysis

This meta-analysis sought to outline the current *status quo* of the literature that deals with the interventions designed to foster children's PEBs. We searched for every experimental manipulation, method, or technique used to increase children's PEBs in lab or field settings. We examine the effectiveness of these interventions and the following *a priori* moderators that could affect it. Post-hoc moderators that emerged during the process of coding are presented in Supplementary Information 1.

1.1. *A priori moderators*

1.1.1. *Age*

This work builds on the conjecture that promoting PEBs among children should be easier than in adults because the reasons for inaction concern more the latter than the former. Past research suggests that the younger individuals are, the more they are responsive to interventions promoting pro-environmental attitudes and behaviors (Liefländer & Bogner, 2014; Zelezny, 1999). We thus expected children's age to negatively predict the intervention effectiveness.

1.1.2. *Gender*

Previous research found that women report higher levels of PEBs than men (Lam & Cheng, 2002; Zelezny, 1999), and it is then possible that girls may be more sensitive to pro-environmental interventions than boys.

1.1.3. *Type of intervention*

In considering relevant interventions, we first included two *a priori* categories that have been extensively studied, namely environmental education and social influence. Two additional categories emerged from the literature search, namely eco-schools and interventions based on additive processes (i.e., relying on a combination of several, theoretically distinct principles). These categories emerged *a posteriori.* All categories are presented in the Method section and the Supplementary Information 2.

1.1.4. *PEB measures*

We considered three categories of PEBs: self-reports, field observations, and laboratory observations (see Method). Although self-reports of PEBs are dominant in the literature (Lange & Dewitte, 2019), they may be less than ideal to accurately capture the effects of experimental interventions. Indeed, researchers often do not allow enough time between treatment and the possible noticeable change in subsequent behavior that could be captured through a one-shot, self-reported assessment (Lange et al., 2018). This could result in an underestimation of the effect of an intervention. Still, past research found evidence that recycling interventions yielded stronger effects when self-reports were used than when actual behavior was measured (Porter et al., 1995). Self-reports can be distorted by social desirability responding (Vesely & Klöckner, 2020), self-perception bias (Corral-Verdugo, 1997), or the lack of self-awareness about one's actual adoption of PEBs and they correlate only moderately with actual behavior (Kormos & Gifford, 2014). This suggests that self-reports could actually overestimate the effects of pro-environmental interventions. Accordingly, we expected interventions using self-reports to yield greater effect sizes compared with those using field observations and laboratory observations.

1.1.5. *Indoor vs. outdoor interventions*

There has been an increasing amount of research suggesting that contact with nature is a booster of PEBs (Collado et al., 2015; Otto & Pensini, 2017). We thus assumed that outdoor interventions should yield greater effect sizes than those that took place indoors. Some studies were coded as mixed – i.e., they took place both indoor and outdoor – but we had no particular expectations with respect to their corresponding effect sizes.

1.1.6. *Active vs. passive involvement*

Environmental education interventions requiring active involvement from children (i.e., perform a task, create an art project, a garden …) were found to be more effective in promoting PEBs than those that were limited to passive involvement where children simply received information (i.e., read, listen or watch something without discussion or activity) (Zelezny, 1999). This is consistent with work conducted on the role of commitment to a behavior in predicting future behavior (Kiesler, 1971). We thus expected environmental education interventions involving children actively to be more effective in promoting PEB than those involving them passively.

2. Method

2.1. *Operational definitions*

A PEB is defined as every action that benefits the environment, harms it in the least way possible or omits to harm it (Steg & Vlek, 2009). Thus, a measure of PEB refers to "all attempts to quantify observable properties (i.e., frequency, latency, temporal extent, intensity) of behaviors that impact the natural environment" (Lange & Dewitte, 2019, p. 92). While these conceptual definitions seem straightforward, the literature is filled with an abundance of various measures used to assess PEBs. In their review, Lange and Dewitte (2019) noted that environmental psychology researchers use highly diverse, ad-hoc PEB measures that are often devised to address specific research questions. They distinguished three broad categories of PEB measures: 1) self-report measures; 2) field observations; 3) laboratory observations. For the purpose of the present meta-analysis, we espouse the classification laid out by Lange and Dewitte (2019) and review successively each of the categories, with an eye to work conducted with children. This will allow us to identify PEBs with *a priori*, theory-driven categories.

2.1.1. *Self-report measures*

Self-report assessment involves asking individuals to explicitly report on their daily or otherwise regular activities, most of the time by filling in a questionnaire. Questions included in such instruments focus on the properties, the frequency of occurrence or the intensity of actions that individuals perform in everyday life with regards to the environment (Lange & Dewitte, 2019). Such questions can be either specific to some particular ecological issues – such as water conservation (Zhan et al., 2019) or energy conservation (Osbaldiston & Schmitz, 2011) – or they can refer to pro-environmental behaviors in general (Culen & Volk, 2000; Ramsey, 1993). Among domain-general, self-report PEB measures with established psychometric qualities, the General Ecological Behavior scale (Kaiser, 1998; Kaiser & Wilson, 2004; Tucker & Izadpanahi, 2017) is widely acknowledged and frequently used by researchers (Lange & Dewitte, 2019). However, since many questions composing such questionnaires are specific to adult behavior (e.g., "at red traffic lights, I keep the engine running") (Kaiser & Wilson, 2004), adaptations and original instruments were also developed for children (Evans et al., 2007; Leeming et al., 1995).

2.1.2. Field observations

Lange and Dewitte (2019) differentiated three types of PEB measures that are included in this category: 1) informant reports; 2) trained observers and 3) device measurements. Informant reports consist in measuring the extent to which a target individual displays PEBs by asking close acquaintances (e.g., family members, co-workers) to report on target individual's behaviors. Informants can be asked to report on past PEBs based on their casual observations of the target individual, or they can be requested to observe target individuals for a given period of time and report on PEBs subsequently. For instance, Mahasneh et al. (2017) measured PEBs by asking parents to record the frequencies of resources conservation and littering behaviors displayed by their children after the latter participated in an environmental intervention. In their format, such reports closely resemble self-report measures as they also tend to rely on questionnaires and scales. Alternatively, trained observers – i.e., researchers themselves or their trained research assistants – can observe and measure target's PEBs directly instead of relying on recruits. Such behavioral assessments can be conducted either in naturalistic environments (e.g., a public swimming pool) (Reich & Robertson, 1979) or in more contrived settings (e.g., a conservation education camp) (Bexell et al., 2013). For instance, Bexell et al. (2013) had instructors to fill in behavioral instructional sheets that assessed children's behaviors towards animals and nature displayed during a one-week education camp. Trained observers can either focus directly on individuals' PEB (Bexell et al., 2013; Mahasneh et al., 2017) or they can measure the product of behaviors (Lange & Dewitte, 2019), such as counting the number of littered paper sheets (Reich & Robertson, 1979). Finally, when it comes to the measurement of PEB products, researchers also resort to various technological devices (Lange & Dewitte, 2019). Examples include utility meters that are widely used to track water, gas or electricity consumption (Abrahamse et al., 2005; Barata et al., 2017), or simply weighting the proportions of recycled thrash (Luyben & Bailey, 1979; Meng & Trudel, 2017). However, it is important to keep in mind that device measurement often produce group-level data (i.e., households, classrooms, schools), and thus needs to be interpreted as such.

2.1.3. Laboratory observations

The last category includes measures of behaviors that are displayed in artificial, constrained settings that are set up for the purpose of a study. Examples include using unobtrusive opportunities when study participants can display a PEB, money allocation to pro-environmental organizations, or disposing of the thrash for a mock task (Lange & Dewitte, 2019). In research that specifically addressed PEBs in children, experimental paradigms very often relied on decision making (Hadjichambis et al., 2015; Huber et al., 2017) or resource dilemmas (Ebersbach & Brandenburger, 2020; Ebersbach et al., 2019). For instance, in Hadjichambis et al. (2015), children were asked to compose a picnic and choose between sustainable and unsustainable options (e.g., personal, single-use bottle of water made of plastic vs. big, multiple-use bottle of water made of glass). Likewise, in Huber et al. (2017), children participated in an entrepreneurship program and were offered the possibility to decide on the extent to which they wanted to use sustainable material or a more attractive, regular material to design their own product. A popular, resource dilemma task with established psychometric properties is the FISH task (Ebersbach & Brandenburger, 2020; Ebersbach et al., 2019; Gifford & Wells, 1991; Spada et al., 1987). Herein, children are matched in groups and asked to act as fishers who decide across several rounds the number of fish they wish to catch. The number of fish that are left after each round is doubled for the next round. Hence, the task implies a 50% threshold of optimal fishing that warrants the sustainability of fish in the lake. If more than 50% of fish are caught each round, the lake is eventually depleted. Since children make individual decisions but draw fish from a common lake, it creates a commons dilemma (Hardin, 1968): they can either maximize individual short-term gains or favor long-term management of a common resource. For instance, Ebersbach et al. (2019) used the FISH task and operationalized the PEB measure by a sustainability index. For each child, they computed a mean difference between the optimal number of fish and the actual number of fish drawn each round.

2.2. Literature review

We conducted a systematic and computer-based search in the literature to find all the available evidence on the effectiveness of interventions fostering PEBs in children. The search was conducted between April 2020 and February 2021 via PsycINFO, PsycARTICLE, ERIC and Web of Science, using 54 search strings (see Supplementary Table 1 and Supplementary Online Materials 1–2). Once we finished the screening process with electronic databases, we also examined the relevance of references included in the published meta-analyses that addressed similar questions (van de Wetering et al., 2022; Zelezny, 1999) (see Supplementary Online Material 2). We also ran a manual Google Scholar search. We contacted authors if their studies seemed relevant but lacked sufficient details warranting inclusion in the meta-analysis. We screened the references sections of the papers that were included in the meta-analysis. Finally, we reached out for several research communities through public forums and mailing lists asking for unpublished papers or datasets that satisfied our inclusion criteria. The call was published by the following associations: *Society of Personality and Social Psychology, American Educational Research Association, European Association for Social Psychology, Environmental Psychology Division of International Association of Applied Psychology and American Psychological Association, division 34: Society for Environmental, Population and Conservation Psychology.*

2.2.1. Inclusion and exclusion criteria

We screened the literature in the search for articles that satisfied the following criteria.

1) Peer-reviewed journal article.
2) The age of participants was less than 18 years; we chose this threshold to define children because it corresponds to the United Nations definition of "every human being below the age of eighteen years", from the Convention on the Rights of the Child (Article 1; UN General Assembly, 1989).
3) Included an experimental manipulation comparing a treatment to a control group (either in laboratory settings or in a field study) aimed at promoting PEBs *or* an intervention aimed at increasing PEBs, the effect of which was assessed through a pre-test and a post-test PEB measure (as described in the criterion below).
4) Include a quantitative measure of PEB (Lange & Dewitte, 2019).

We were interested in how PEBs can be promoted in children and consequently restricted our meta-analysis to studies that included pro-environmental interventions. Thus, correlational studies were excluded. Studies that assessed the impact of interventions in children on outcomes such as knowledge or attitudes but not PEBs were likewise not included in our meta-analysis. We excluded studies that assessed behavioral intentions but did not contain measurements of children's behaviors, or whose measure of PEB was confounded with a measure of behavioral intentions. Finally, we excluded studies where the only available PEB measure referred to household behaviors, and studies with adults as participants. Studies had also to be excluded whenever we did not have sufficient statistics to compute an effect size and it was impossible to reach the authors, or the data were unavailable. One reference was excluded because the sample size used in the study was too small. One study was excluded because the PEB measure suffered from methodological problems. References were excluded whenever the full text could not be retrieved. No language or publication date restrictions were implemented in the literature search. In order to assess the eligibility of papers written in languages we did not master, we relied on colleagues who were proficient in the given language. Details on the eligibility assessment can be found in Supplementary Online Material 2.

2.2.2. Search results

Fig. 1 displays the PRISMA diagram (Moher et al., 2009) showing the flow of publications through the stages of the literature review. The initial search yielded a total of $k = 10{,}548$ outputs. Firstly, duplicates were removed using Excel utilities. Then, W.Ś. screened the whole

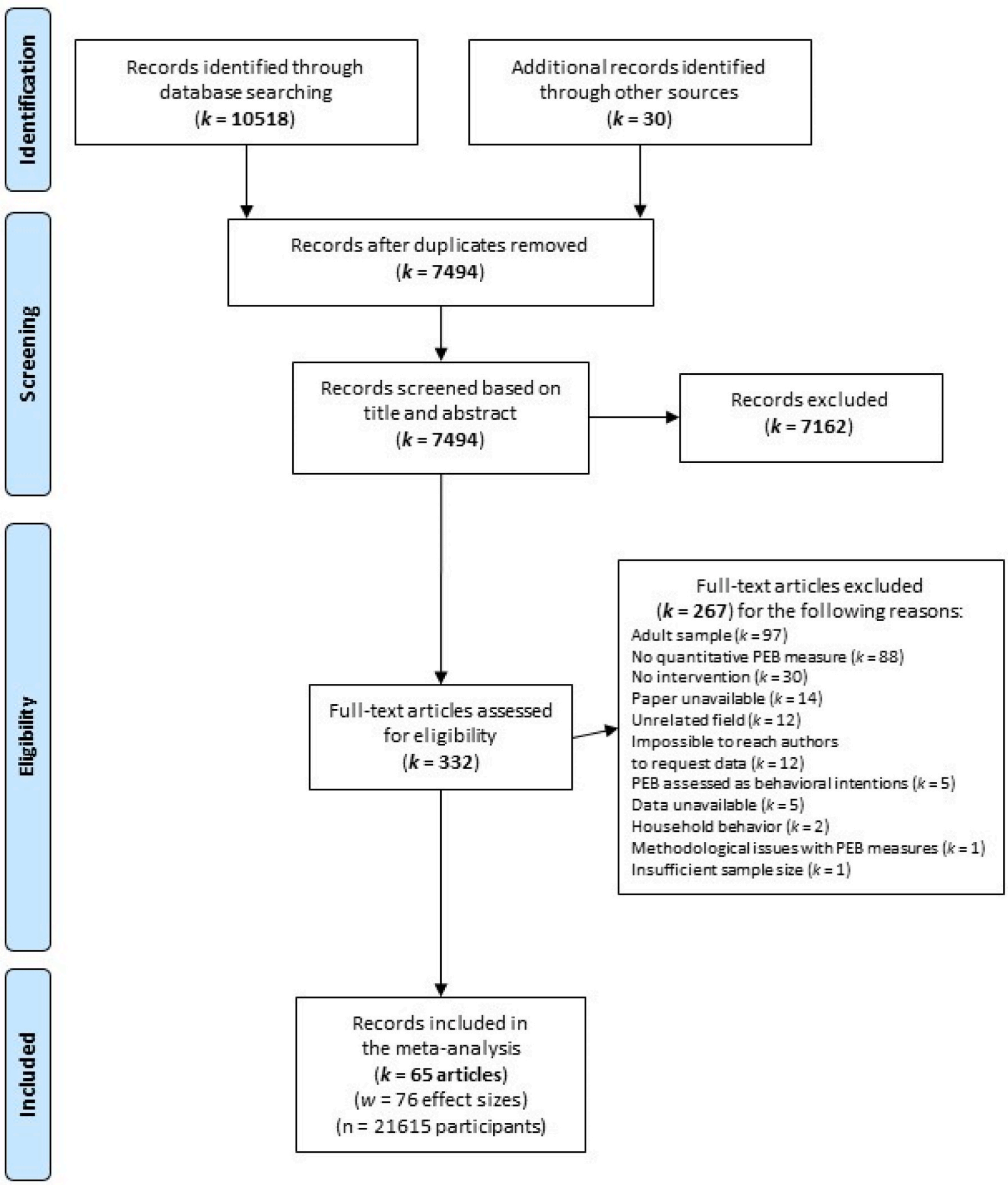

Fig. 1. Prisma flow diagram.

record of references and removed the remaining duplicates manually. The remaining record of $k = 7494$ outputs were screened for eligibility based on the article title and the abstract (see Supplementary Online Material 2). Consequently, the full text of each of the $k = 332$ remaining references was further examined for inclusion in the meta-analysis (see Supplementary Online Material 3). Applying our search criteria led us to retain 65 published papers. All searches, study screenings and eligibility assessment for the inclusion were conducted by W.Ś. and consulted with F.B.

2.2.3. Coding

Articles were coded based on descriptive information: 1) author(s), 2) year of publication, 3) continent where data collection took place, 4) research outcome(s) (single or multiple); sample characteristics: 5) sample size, 6) children's age, 7) proportion of female participants; characteristics of the intervention: 8) type of intervention (environmental education, social influence, eco-school, additive processes), 9) place of intervention (outdoor, indoor, both outdoor and indoor), 10) involvement from children (active or passive), 11) study design (between-participant, within-participant, mixed), 12) the type of learning experience (direct or indirect) if relevant; characteristics of the outcome measure: 13) the type of PEB assessed in the study, 14) the type of self-reported scale used to assess PEBs (validated, adapted, *ad hoc*) if relevant; 15) children's participation in intervention (individually or in groups); 16) the effect size. When the country of data collection was not explicitly mentioned in the article, it was assumed based on the first author's affiliation. Unless stated otherwise, articles were coded by W.Ś. and discussed with F.B. in case of uncertainty (see Table 1). Information 4), 11), 12), 14) and 15) were established *a posteriori* and are presented in Supplementary Information 1.

Regarding the sample characteristics, it should be noted that many papers did not report the mean age of the sample explicitly. Children's age was often reported with reference to intervals (e.g., "ages 5–10"), with reference to the grade (e.g., "ninth grade"), or both (e.g., "seventh- and eight-grade classes"). When that was the case, the mean age of the sample was coded as the midpoint of the interval. Students from the 4th, 5th, 6th, 7th, 8th, 9th, 10th, 11th and 12th grades were coded with the mean ages of, 9.5, 10.5, 11,5, 12.5, 13.5, 14.5, 15.5, 16.5. and 17.5 years, respectively, accordingly with the international education system.

Interventions that integrated elements of environmental education were coded with respect to the type of involvement they required from participants (Zelezny, 1999). Studies were coded as requiring active involvement if children were asked to actively engage in performing a task, such as group projects or discussions, hand-on activities or experiences, researching a topic, collecting and analyzing data, writing reports, preparing home assignments, etc. Contrarywise, interventions were coded as requiring passive involvement whenever the intervention consisted in merely information reception, such as attending a lecture or an instruction session, reading documents, watching an instructional film, etc., without discussion or other activity around it.

As far as the characteristics of the intervention were concerned, we relied on the working definition we espoused from the beginning, i.e., theory-based manipulations that aim at identifying levers of change. It was thus decided that the interventions should be coded depending on the content and the principle used in the intervention; in this respect, we used two approaches. As mentioned above, an abundant literature allowed us to select *a priori* (1) interventions based on environmental education, and (2) interventions based on social influence mechanisms (i.e., descriptive or prescriptive norms, role modelling, use of feedback or incentive, group processes). Moreover, we inspected the collected studies for the emergence of other *a posteriori* categories. In this approach, the coding scheme was determined post-hoc, through an inductive process, after reading all the articles retained in the meta-analysis, which was handled by W.Ś. and J.H. and consulted with F.B., namely (3) eco-schools and (4) interventions based on additive processes, i.e., interventions that relied on a combination of several theoretically-distinct principles (e.g., environmental education combined with social comparison, social comparison combined with self-efficacy training, cooperative learning combined with cognitive training, etc.). The characteristics of the intervention types are reviewed in Supplementary Information 2.

PEB measures were coded according to the three main categories: 1) self-reported scales, 2) field observations and 3) laboratory observations (Lange & Dewitte, 2019). In studies using self-reported scales, participants are asked to report on their PEBs by filling in questionnaires. Studies using field observations assess participants' PEBs without relying on their subjective reports but rely either on informant reports, trained observers, or device measurement. Studies using laboratory observations expose participants to contrived situations where their PEBs can be directly observed (see above).

2.3. Meta-analytical strategy

The dependent variable was the standardized mean difference between: 1) the intervention and the control conditions in a between-participant design, or 2) the pretest and the posttest scores in a within-participant design, or 3) the growth scores (the change from the pretest to posttest) in the intervention and the control conditions in a mixed design. Then, we chose to standardize the mean differences using Hedges' *g*. We used it instead of Cohen's *d* because it corrects for small sample sizes (Borenstein et al., 2009). In order to test the efficacy of pro-environmental interventions, the effect sizes were subjected to a random-effects linear model meta-analysis (Borenstein et al., 2009). Computations were ran using the *metafor* package (Viechtbauer, 2010) in R (R Core Team, 2015).

Effect sizes were calculated following two approaches. Firstly, effect sizes were computed based on either summary statistics (raw means, standard deviations, and sample sizes) or summarized data reported in the paper, or raw data obtained from authors upon request. Otherwise, effect sizes that could have not been computed directly were obtained through conversions. Effect sizes reported as the *t*-, *F*-, Chi^2-statistic, *odds-ratio* and *beta* regression slopes were extracted along with the relevant statistics (i.e., sample size, standard-error, or both) and transformed into Hedges' *g* effect sizes and the associated variances using *esc* package utilities (2019). Effect sizes reported as the *Pearson's r* correlation coefficients were retrieved along with the sample sizes and transformed into Hedges' *g* also using the *esc* package. The corresponding variances were obtained using the formula:

$$V_g = \frac{4V_r}{(1 - r^2)^3}$$

where *r* is the correlation coefficient, V_r is the variance of *r* and V_g is the target variance (Borenstein et al., 2009). Variances V_r were obtained using the *metafor* package utilities. Finally, effect sizes reported as η^2 and *Z*-values from the Wilcoxon matched-pair signed ranked test were first transformed into *Pearson's r* correlation coefficients using the *esc* package and *Psychometrica* utilities (2016). From there, Hedges' *g* effect sizes and the corresponding variances and were obtained as described above.

Note that for $w = 13$ samples, we first computed the Chi^2-statistic based on the data summarized in the papers and then converted it into the Hedge's *g* effect size as described above. For $w = 3$ samples, we used the paired-samples *t-test* statistic and converted it into *Pearson's r* correlation coefficient using the *effectsize* package (Ben-Shachar et al., 2020) and then transformed it into Hedge's g as described above. For $w = 2$ samples involving a mixed design, *Z*-values from the Wilcoxon matched-pair signed ranked test (i.e., testing for the difference between the pre-test and post-test scores) were first transformed into *Pearson's r* correlation coefficients and then used to compute Cohen's *q*, which quantified the difference in growth scores between the treatment and control conditions. Cohen's *q* was computed using *Psychometrica* (Lenhard & Lenhard, 2022) utilities and then converted into Hedges' *g* using

Table 1
Summary of studies included in the meta-analysis.

Study name	Continent (Country)	Sample Size	Age in Years	Fraction of females	Study design	PEB Measure	Self-reported Scale	Type of Intervention	Place	Involvement	Type of Learning	Participation	Outcome (s)	Hedges' *g*
Adler et al. (2016)	Middle East (Israel)	144	13.5		Mixed	Self-report	Adapted	Additive Processes	Mixed	Active	Direct	In groups	Multiple	0.14
Aird and Tomera (1977)	North America (USA)	50	11.5		Between	Self-report	*Ad hoc*	EE	Indoor	Active	Direct	In groups	Multiple	1.57
Asch and Shore (1975)	North America (Canada)	24 [a]	10.5	0	Between	Trained observers	NA	EE	Mixed	Active	Direct	In groups	Single	1.67
Barata et al. (2017)	Europe (Portugal)	343	13	0.49	Between	Self-report	*Ad hoc*	EE	Mixed	Active	Direct	In groups	Multiple	0.27
Baur and Haase (2015)	Europe (Germany)	246	11	0.48	Mixed	Laboratory observation	NA	Additive Processes	Indoor	Active	Indirect	In groups	Multiple	0.93
Bernstein and Puttick (2014; Study 1)	North America (USA)	37	12.8	1	Mixed	Self-report	Adapted	Social Influence	Indoor	NA	NA	In groups	Multiple	0.23
Bernstein and Puttick (2014; Study 2)	North America (USA)	23	12.3	1	Mixed	Self-report	Adapted	Social Influence	Indoor	NA	NA	In groups	Multiple	0.43
Bernstein and Puttick (2014; Study 3)	North America (USA)	55	11.2	1	Mixed	Self-report	Adapted	Social Influence	Indoor	NA	NA	In groups	Multiple	0.18
Bexell et al. (2013; Chengdu ZOO Sample)	Asia (China)	23[a]	10	0.51	Within	Informant report	NA	EE	Outdoor	Active	Direct	In groups	Multiple	0.63
Bexell et al. (2013; Research Base Sample)	Asia (China)	23[a]	10	0.26	Within	Informant report	NA	EE	Outdoor	Active	Direct	In groups	Multiple	0.55
Beyer et al. (2015)	North America (USA)	255	11		Mixed	Self-report	*Ad-hoc*	EE	Mixed	Active	Direct	In groups	Multiple	0.64
Bodzin et al. (2013)	North America (USA)	839	14	0.54	Mixed	Self-report	Adapted	EE	Indoor	Active	Indirect	In groups	Multiple	0.14
Boeve-de Pauw & Van Petegem (2013)	Europe (Belgium)	1287	11.2	0.51	Between	Self-report	Validated	Eco-School	Indoor	NA	NA	In groups	Multiple	0.12
Bogner (1998; 1-day program)	Europe (Germany)	322	12.3		Within	Self-report	Validated	EE	Outdoor	Active	Direct	In groups	Multiple	0.07
Bogner (1998; 5-day program)	Europe (Germany)	333	12.3		Within	Self-report	Validated	EE	Outdoor	Active	Direct	In groups	Multiple	0.29
Bogner (1999)	Europe (Switzerland)	301	12.7	0.48	Mixed	Self-report	Validated	EE	Mixed	Active	Direct	In groups	Multiple	0.21
Boudet et al. (2016)	North America (USA)	310	9.6	1	Between	Self-report	Adapted	Additive Processes	Mixed	Active	Indirect	In groups	Multiple	0.73
Burnett et al. (2016)	Africa (Cape Verde)	449	14	0.53	Mixed	Self-report	Adapted	EE	Outdoor	Passive	Direct	In groups	Multiple	0.16
Charry and Parguel (2019)	Europe (Belgium)	97	10	0.54	Mixed	Self-report	*Ad hoc*	Social Influence	Indoor	NA	NA		Multiple	0.36
Collado et al. (2020)	Europe (Spain)	734	8.6	0.51	Mixed	Self-report	Validated	EE	Mixed	Active	Direct	In groups	Multiple	0.05
Cornelius et al. (2014)	North America (USA)	165	15.5	0.58	Between	Self-report	Adapted	Additive Processes	Indoor	Active	Indirect	In groups	Multiple	0.37
Culen and Volk (2000)	North America (USA)	245	13		Between	Self-report	*Ad hoc*	EE	Indoor	Active	Direct	In groups	Multiple	0.54
Dresner and Gill (1994)	North America (USA)	28	11.5		Within	Self-report	*Ad hoc*	Additive Processes	Outdoor	Active	Direct	In groups	Multiple	2.49
Drissner et al. (2010)	Europe (Germany)	182	11	0.52	Mixed	Self-report	Validated	EE	Outdoor	Active	Direct	In groups	Multiple	−0.17
Duerden and Witt (2010)	North America (USA)	157	14.2	0.52	Mixed	Self-report	Validated	EE	Mixed	Active	Direct	In groups	Multiple	0.39
Ebersbach and Brandenburger (2020)	Europe (Germany)	132	10.8	0.49	Mixed	Laboratory observation	NA	Social Influence	Indoor	NA	NA	In groups	Single	1.27

(*continued on next page*)

Table 1 (*continued*)

Study name	Continent (Country)	Sample Size	Age in Years	Fraction of females	Study design	PEB Measure	Self-reported Scale	Type of Intervention	Place	Involvement	Type of Learning	Participation	Outcome (s)	Hedges' *g*
Ebersbach et al. (2019)	Europe (Germany)	115	8.7	0.53	Within	Laboratory observation	NA	Social Influence	Indoor	NA	NA	In groups	Single	2.33
Erdogan (2011)	Middle East (Turkey)	53	10.9	0.4	Within	Self-report	Adapted	EE	Outdoor	Active	Direct		Multiple	0.89
Erdogan (2015)	Middle East (Turkey)	44	11.3	0.44	Within	Self-report	Adapted	EE	Outdoor	Active	Direct	In groups	Multiple	0.50
Fidan and Ay (2016)	Middle East (Turkey)	20	9.5	0.45	Within	Self-report	*Ad hoc*	EE	Indoor				Multiple	1.88
Fröhlich et al. (2013)	Europe (Germany)	176	11.5	0.54	Within	Self-report	Validated	EE	Mixed	Active	Direct	In groups	Multiple	0.16
Goodwin et al. (2010)	Europe (United Kingdom)	307	8		Mixed	Self-report	*Ad hoc*	EE	Indoor	Active	Indirect	In groups	Multiple	−0.02
Gottlieb et al. (2013)	Middle East (Israel)	200	16.5		Between	Self-report	Validated	EE	Indoor	Active	Direct	In groups	Multiple	0.18
Grodzińska-Jurczak et al. (2003)	Europe (Poland)	284	12	0.48	Within	Self-report	*Ad hoc*	EE	Mixed	Active	Indirect	In groups	Multiple	0.17
Hadjichambis et al. (2015)	Europe (Cyprus)	286	10	0.55	Within	Laboratory observation	NA	EE	Indoor	Active	Direct		Multiple	1.72
Hartley et al. (2015)	Europe (United Kingdom)	107	10.4	0.57	Within	Self-report	*Ad hoc*	EE	Indoor	Active	Direct	In groups	Multiple	0.37
Hsiao and Shih (2016)	Asia (Taiwan)	11	5.7	0.55	Within	Informant report	NA	EE	Indoor	Active	Indirect	In groups	Multiple	2.76
Huber et al. (2017)	Europe (Netherlands)	1297 [a]	11.7	0.5	Between	Device measurement	NA	Social Influence	Indoor	NA	NA	In groups	Multiple	0.34
Johnson and Manoli (2008)	North America (USA)	625	11		Mixed	Self-report	Validated	EE	Mixed	Active	Direct	In groups	Multiple	0.36
Jordan et al. (1986)	North America (USA)	57			Between	Self-report	*Ad hoc*	EE	Outdoor	Passive	Indirect	In groups	Multiple	0.63
Keramitsoglou and Tsagarakis (2011)	Europe (Greece)	178	16.5		Within	Self-report	*Ad hoc*	EE	Indoor	Active	Indirect	In groups	Multiple	0.29
Kerret et al. (2020)	Middle East (Israel)	1903	11	0.5	Between	Self-report	*Ad hoc*	Eco-School	Indoor	NA	NA	In groups	Multiple	0.19
Kurtz et al. (1976)	North America (USA)	15	3.8	0.6	Mixed	Laboratory observation	NA	Social Influence	Indoor	NA	NA	Individually	Single	1.14
Kwan et al. (2017, pp. 2012–2013 Sample)	Asia (Hong-Kong)	47	15		Within	Self-report	*Ad hoc*	EE	Mixed	Active	Direct	In groups	Multiple	1.09
Kwan et al. (2017, pp. 2013–2014 Sample)	Asia (Hong-Kong)	64	15		Within	Self-report	*Ad hoc*	EE	Mixed	Active	Direct	In groups	Multiple	1.31
Kwan et al. (2017, pp. 2014–2015 Sample)	Asia (Hong-Kong)	184	15		Within	Self-report	*Ad hoc*	EE	Mixed	Active	Direct	In groups	Multiple	0.31
Lee et al. (2013)	Asia (Taiwan)	119	11		Mixed	Self-report	Adapted	EE	Indoor	Active	Direct	In groups	Multiple	0.44
Lin (2016)	Asia (Taiwan)	66	13.5	0.50	Mixed	Self-report	*Ad hoc*	Additive Processes	Indoor	Active	NA	Individually	Multiple	0.64
Locritani et al. (2019)	Europe (Italy)	87	16		Within	Self-report	Adapted	EE	Mixed	Active	Direct	In groups	Multiple	0.75
Luyben and Bailey (1979; Brittany Estates Sample)	North America (USA)	36	8.6		Within	Device measurement	NA	Social Influence	Outdoor	NA	NA	Individually	Single	0.95
Luyben and Bailey (1979; Coach Estates Sample)	North America (USA)	13	8.5		Within	Device measurement	NA	Social Influence	Outdoor	NA	NA	Individually	Single	0.44
Luyben and Bailey (1979; Windmill Village Sample)	North America (USA)	12	6		Within	Device measurement	NA	Social Influence	Outdoor	NA	NA	Individually	Single	0.29
Mahasneh et al. (2017)	Middle East (Jordan)	522			Between	Informant report	NA	Additive Processes	Indoor		Direct	In groups	Multiple	0.82

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Table 1 (*continued*)

Study name	Continent (Country)	Sample Size	Age in Years	Fraction of females	Study design	PEB Measure	Self-reported Scale	Type of Intervention	Place	Involvement	Type of Learning	Participation	Outcome (s)	Hedges' *g*
Meng and Trudel (2017)	North America (USA)	750	7.5		Within	Device measurement	NA	Social Influence	Indoor	NA	NA	In groups	Single	0.75
Middlestadt et al. (2001)	Middle East (Jordan)	433	15.6	0.65	Between	Self-report	*Ad hoc*	EE	Indoor	Active	Direct	In groups	Multiple	0.23
Olsson et al. (2019)	Asia (Taiwan)	1741	15	0.54	Between	Self-report	Validated	Eco-School	Indoor	NA	NA	In groups	Multiple	0.07
Osbaldiston and Schmitz (2011)	North America (USA)	67	14.5		Within	Self-report	*Ad hoc*	Additive Processes	Indoor	Active	Direct	In groups	Multiple	0.79
Owen et al. (2009)	America (USA)	414	15	0.72	Within	Self-report	*Ad hoc*	EE	Outdoor	Active	Direct		Multiple	0.17
Pan and Hsu (2020)	Asia (Taiwan)	173	11.5		Mixed	Self-report	*Ad hoc*	EE	Mixed	Active	Indirect	In groups	Multiple	0.48
Puttick et al. (2015; Junior Sample)	America (USA)	235	10	1	Within	Self-report	*Ad hoc*	Additive Processes	Mixed	Active	NA	In groups	Multiple	0.19
Puttick et al. (2015; Cadette Sample)	America (USA)	121	13	1	Within	Self-report	*Ad hoc*	Additive Processes	Mixed	Active	NA	In groups	Multiple	0.39
Ramsey and Hungerford (1989)	North America (USA)	149 [a]	12.5		Between	Self-report	Adapted	EE	Indoor	Active	Indirect	In groups	Multiple	3.15
Ramsey et al. (1981)	North America (USA)	65	13.5		Between	Self-report	*Ad hoc*	EE	Indoor	Active	Indirect	In groups	Multiple	0.9
Ramsey (1993)	North America (USA)	182 [a]	13.5		Between	Self-report	Adapted	EE	Indoor	Active	Indirect	In groups	Multiple	2.04
Reich and Robertson (1979Reich and Robertson (1979; Study 1)	North America (USA)	60			Between	Trained observers	NA	Social Influence	Outdoor	NA	NA	Individually	Single	0.65
Reich and Robertson (1979Reich and Robertson (1979; Study 2)	North America (USA)	120			Between	Trained observers	NA	Social Influence	Outdoor	NA	NA	Individually	Single	0.24
Reich and Robertson (1979Reich and Robertson (1979 Study 3)	North America (USA)	120			Between	Trained observers	NA	Social Influence	Outdoor	NA	NA	Individually	Single	0.5
Shay-Margalit and Rubin (2017)	Middle East (Israel)	586	10.5	0.47	Between	Self-report	Adapted	Eco-School	Indoor	NA	NA	In groups	Multiple	0.25
Spínola (2015)	Europe (Portugal)	486	15	0.49	Between	Self-report	Adapted	Eco-School	Indoor	NA	NA	In groups	Multiple	0.19
Stevenson et al. (2013)	North America (USA)	739	12.7		Between	Self-report	*Ad hoc*	Eco-School	Indoor	NA	NA	In groups	Multiple	−0.06
Stevenson et al. (2018)	North America (USA)	1041	12.5	0.52	Between	Self-report	Adapted	EE	Mixed	Active	Direct	In groups	Multiple	0.06
To-Im and Klunklueng (2012)	Asia (Thailand)	20	14.5		Within	Self-report	Adapted	EE	Mixed	Active	Direct	In groups	Multiple	1.84
Tucker and Izadpanahi (2017)	Oceania (Australia)	275	11		Between	Self-report	Validated	Eco-School	Indoor	NA	NA	In groups	Multiple	0.75
Volk and Cheak (2003)	North America (USA)	66	11		Between	Self-report	*Ad hoc*	EE	Indoor	Active	Indirect	In groups	Multiple	−0.78
Wang (2014)	Asia (Taiwan)	57	10.5	0.51	Mixed	Self-report	Adapted	EE	Indoor	Active	Indirect	In groups	Multiple	1.30
Zhan et al. (2019)	Asia (China)	69	7	0.31	Within	Self-report	*Ad hoc*	EE	Indoor	Active	Direct	In groups	Multiple	1.08

Note. Blanks indicate that data were not available; EE = Environmental Education; [a] indicates that study's sample size does not match with the number of degrees of freedom based on which the effect size was computed.

the *esc* package (Lüdecke, 2019). For $w = 1$ sample, we followed the same approach as above with the exception that Chi^2-statistics were used to obtain correlation coefficients.

It should be noted that for $k = 4$ papers for which we did not receive an answer from authors, results were reported as multiple regressions analyses where the main effect of the intervention was controlled for various control variables (e.g., age, gender, SES, …). We included such effects sizes in the meta-analysis irrespective of the control variables that were included in the original analyses.

Details on effect size computations are available in Supplementary Online Material 3.

In $w = 19$ studies, multiple PEB measures by participant were reported. To ensure statistical independence of effect sizes contributing to the overall effect size, one effect size per study was allowed. Thus, aggregate effect sizes were extracted from these studies by computing the average effect size. In $k = 7$ papers, several independent subgroups or samples were included, so they were treated as independent samples in the meta-analysis (Borenstein et al., 2009).

Note that several references that were found in van de Wetering et al. (2022) were included in the present meta-analysis, but they were not

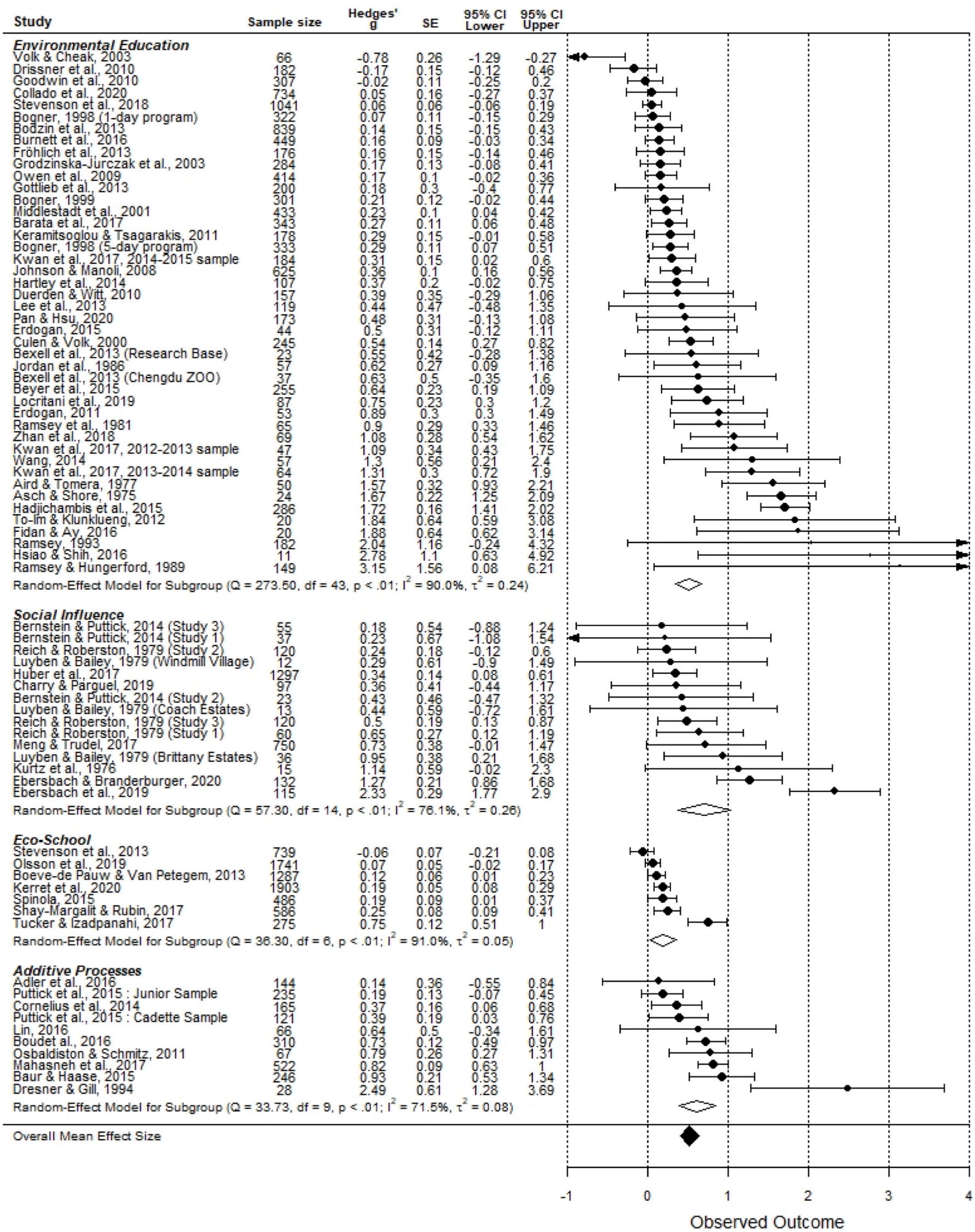

Fig. 2. Forest plot of individual and summary effects size estimates, stratified by the type of intervention.

coded to the same effect sizes as in the former meta-analysis. This is because we questioned several effect sizes in van de Wetering et al. due to coding decisions that are apparent in their supplementary material. For instance, the authors coded the effect size for Hsiao and Shih (2016) by averaging pretest and posttest raw scores on a 10-item scale, where one item is reversed (#3). However, the authors did not recode the score on the reverse item prior to computing the pretest and posttest average scores. Furthermore, it appears that van de Wetering et al. relied on paired-samples summary statistics – such as paired-samples *t-test* values – to code for several effect sizes but used utilities intended for independent-samples statistics, which leads to biased estimates for a number of papers (e.g., Erdogan, 2011; Fidan & Ay, 2016; Fröhlich et al., 2013; To-Im & Klunklueng, 2012).

2.4. Test of moderators

Moderator analyses included those that were determined *a priori* and those that were exploratory, either identified during the coding process or regarding which we had no *a priori* expectations. Moderator analyses were planned *a priori* for: 1) age; 2) percentage of females in the sample; 3) the type of intervention; 4) the type of PEB measure; 5) place of the intervention; 6) children's involvement in the intervention. Exploratory moderator analyses were conducted *a posteriori* for: 7) year of publication; 8) continent of data collection; 9) type of learning; 10) study design; 11) children's participation in the intervention; 12) self-reported scale. Since the moderators 6) and 9) coded specifically for different approaches to learning, only environmental education interventions were included in the analyses of these moderators (namely, Environmental Education Interventions or Additive Processes Interventions). The moderator 12) applies only to studies that relied on self-reported measures to assess PEBs. Moderator analyses were conducted as univariate meta-regressions, provided that at least 10 studies per covariate could be included in the analysis (Borenstein et al., 2009). If such a condition was not met, we conducted subgroup analyses (i.e., separate, random-effects linear model meta-analyses were computed). Details on the exploratory moderator analyses are presented in Supplementary Information 3. Prior to the moderator analyses, cases with missing values were excluded.

3. Results

The $k = 65$ articles included in the meta-analysis consisted of $w = 76$ independent samples and are summarized in Table 1. All articles were published in English between 1975 and 2020, with the median year of publication of 2013. The total number of participants included in the studies was $n = 21{,}615$ ($M_{\text{sample size}} = 284.4$, $SD_{\text{sample size}} = 377.3$). Fig. 2 displays the forest plot of the meta-analysis with individual and summary effect sizes stratified by intervention type. Overall, there was a statistically significant effect of interventions on children's PEBs of medium size, $g_{overall\ effect} = 0.53$, $SE = 0.06$, $Z = 8.57$, *95% CI* = [0.41, 0.65], $p < 0.001$. Studies were highly heterogeneous, $Q(75) = 497.75$, $I^2 = 91.24\%$, $T^2 = 0.21$, $p < 0.001$. The average effect size was robust to the absence of the outliers (see Supplementary Information 4). There was evidence for a slight publication bias as showed by Egger's regression test (Egger et al., 1997) for funnel plot asymmetry, $Z = 5.02$, $p < 0.001$ (see Supplementary Fig. 1). The adjusted effect size based on the trim-and-fill procedure (Duval & Tweedie, 2000) was $g_{adjusted\ effect} = 0.46$, $SE = 0.07$, $Z = 6.84$, *95% CI* = [0.33, 0.60], $p < 0.001$. While the overall effect size was therefore robust to publication bias, our post-hoc coding and analyses indicated that studies that specifically used behavioral measures (i.e., field and laboratory observations) were at a high risk of distortion by publication bias (see Supplementary Information 5).

3.1. Moderators of effect sizes

3.1.1. Age

Age was a statistically significant predictor of effect size, $Q(1) = 4.09$, $p < 0.05$, accounting for 5% of between-study variance. As displayed on Fig. 3, this relationship between children's age and effect size was negative, $b = -0.05$, $SE = 0.03$, $Z = -2.02$, *95% CI* = [−0.11, −0.00]. On average, studies with older children were associated with smaller effect sizes than studies with younger children.

3.1.2. Gender

We found no statistically significant relationship between the proportion of female participants and the effect size magnitudes, $Q(1) = 2.90$, $p = 0.09$.

3.1.3. Type of intervention

Most interventions were based on environmental education (58%), followed by social influence (20%), additive processes (13%), and eco-schools (9%). The low number of studies reported in the last two categories precluded moderation analyses, hence we computed the mean effect size for each category instead: $g_{environmental\ education} = 0.52$, $k = 44$, $SE = 0.08$, $Z = 6.13$, $p < 0.001$, *95% CI* = [0.35, 0.69]; $g_{social\ influence} = 0.71$, $k = 15$, $SE = 0.16$, $Z = 4.32$, $p < 0.001$, *95% CI* = [0.39, 1.03]; $g_{additive\text{-}processes} = 0.62$, $w = 10$, $SE = 0.11$, $Z = 5.45$, $p < 0.001$, *95% CI* = [0.40, 0.84]; $g_{eco\text{-}schools} = 0.20$, $w = 7$, $SE = 0.09$, $Z = 2.32$, $p < 0.03$, *95% CI* = [0.03, 0.37]. Supplementary Information 2 further includes the phenomenology of each type of intervention to represent the type of studies conducted in this domain, which can be useful to researchers who would like to contribute to the field.

3.1.4. PEB measures

Self-reports were used in the majority of studies (76%), followed by field observations (17%) and laboratory observations (7%). Because of the low number of studies that used field and laboratory observations, we did not test the moderating role played by the type of PEB measure on the effect size magnitude as intended. Given our expectations and the strong prevalence of self-reports over the two others, we tested instead whether the former differed from the latter in terms of effect sizes. We thus compared self-reports to behavioral measures (i.e., field and laboratory observations considered altogether). The analysis yielded a statistically significant moderation of effect sizes, $Q(1) = 18.55$, $p < 0.001$ and explained 32% of between-study variance. Behavioral measures were associated with a greater effect size ($g_{behavioral\ measures} = 0.95$, $w = 18$, $SE = 0.15$, $Z = 6.37$, $p < 0.001$, *95% CI* = [0.66, 1.25]) than the self-reports ($g_{self\text{-}report\ measures} = 0.37$, $w = 58$, $SE = 0.05$, $Z = 7.36$, $p < 0.001$, *95% CI* = [0.27, 0.47]) (see Supplementary Fig. 2).

3.1.5. Indoor vs. outdoor interventions

Most interventions took place indoor (51%), followed by interventions that took place both indoor and outdoor (26%) and outdoor interventions (22%). The place of the intervention was not a statistically significant moderator of effect size magnitude, $Q(2) = 0.79$, $p = 0.67$. There was no statistically significant difference between interventions that took place indoor ($g_{indoor} = 0.60$, $w = 39$, $SE = 0.10$, $Z = 5.88$, $p < 0.001$, *95% CI* = [0.40, 0.80]), outdoor ($g_{outdoor} = 0.38$, $w = 17$, $SE = 0.09$, $Z = 4.20$, $p < 0.001$, *95% CI* = [0.20, 0.56]) or in mixed settings ($g_{mixed} = 0.48$, $w = 20$, $SE = 0.10$, $Z = 4.90$, $p < 0.001$, *95% CI* = [0.29, 0.68]).

3.1.6. Active vs. passive involvement

Almost all interventions involving environmental education required active involvement from children (96%) and a couple required passive involvement (4%). Subgroups analyses indicated that interventions that required active participation from participants yielded a medium effect size ($g_{active} = 0.54$, $w = 51$, $SE = 0.08$, $Z = 7.13$, $p < 0.001$, *95% CI* = [0.39, 0.68]), while interventions that consisted in passive participation

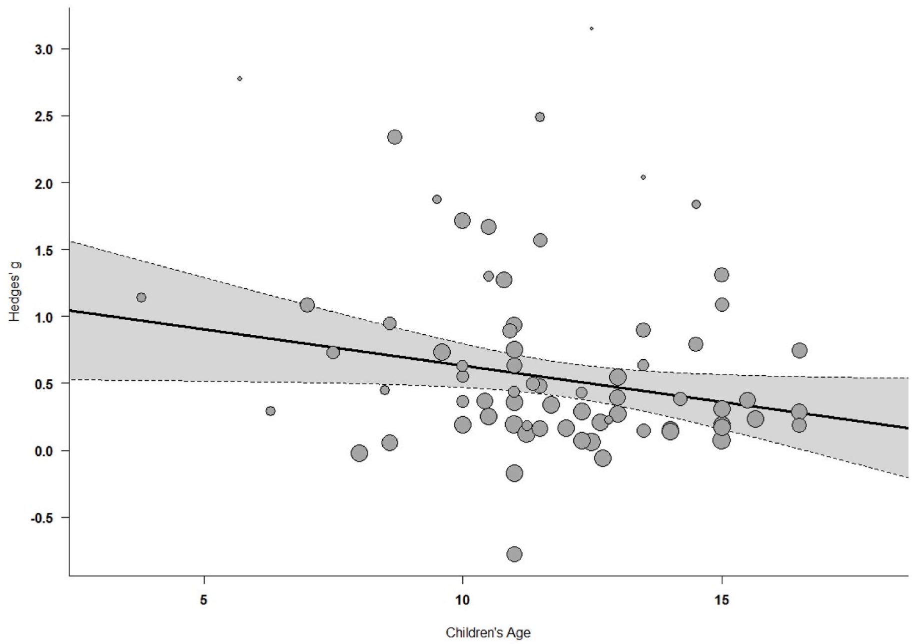

Fig. 3. Scatter plot of effect size estimates as function of children's mean age.

yielded a small effect size ($g_{passive} = 0.32$, $w = 2$, $SE = 0.22$, $Z = 1.43$, $p = 0.15$, *95% CI* = [−0.12, 0.76]).

3.2. Exploratory analyses

Detailed exploratory analyses are reported in Supplementary Information 3. The most noteworthy finding is that only 20% of studies that relied on self-reports used validated instruments, against 80% that used adapted or *ad hoc* instruments. Importantly, the former presented less variance than the latter (see Supplementary Fig. 2). Finally, 83% of studies had children participate in the intervention in groups, against 11% of studies where children participated individually.

4. Discussion

Based on the present meta-analysis of 65 relevant articles, we draw several conclusions and outline a research agenda for future research. Firstly, research on interventions fostering children's PEBs is strikingly scarce ($k = 65$; $n = 21{,}615$). Such a modest record contrasts sharply with the literature on interventions promoting PEBs in adults, (e.g., $n = 277{,}730$ in Bergquist et al. (2019); $n = 3{,}092{,}678$ in Nisa et al. (2019)). Clearly, we are still a long way before we can compare trends emerging from adult and children studies. Secondly, the number of studies that assessed actual – and not self-reported – PEBs is remarkably low, amounting to 13 publications. Strikingly, among the majority of studies relying on self-reports, only 20% used validated instruments. Moreover, half of papers were published after 2013, and the amounts of heterogeneity across studies within each considered category of intervention were found to be substantial. Overall, such a state of the art highlights a picture of an emerging field. Notwithstanding, the available evidence reveals a positive, medium effect of pro-environmental interventions on children's PEBs ($g = 0.53$). Except for the eco-schools that yielded a small effect, subgroup analyses indicated that the effectiveness of interventions based on social influence, environmental education and additive processes were associated with medium effect sizes.

4.1. Factors affecting interventions' effectiveness

As predicted, we found a negative correlation between children's age and intervention effectiveness. This finding is of substantial importance as it means that interventions can produce changes in PEBs more easily in younger than in older children. It is consistent with past research that documented a decrease in environmental concerns such as engagement in PEBs in older as compared with younger children (Krettenauer et al., 2020; Otto et al., 2019). Our findings show that interventions fostering children's PEBs are prone to this age effect and consequently have their effectiveness hampered as children are aging. This is also consistent with the rationale that aging entails the risk of desensitization to environmental concerns through an increasingly stronger influence of social, economic, and cultural barriers that impede a pro-environmental shift (Gifford, 2011). Previous research did not find evidence for this negative correlation (van de Wetering et al., 2022), which we think may have to do with the fact that it was limited to environmental education where children's age is commonly reported with intervals and not precise estimates. This shortcoming could explain why the relationship between age and intervention effectiveness may be harder to observe with such studies. Because our meta-analysis also included interventions where precise estimates of children's age were reported, this relationship could be found. Indeed, when we excluded interventions based on environmental education from the analyses, the negative correlation was even stronger and accounted for 20% of explained variance. Interestingly, it is still possible that the negative correlation between effect size and age is due to a social desirability bias or demand effects (Vesely & Klöckner, 2020) which would increase as children are growing. This is also in line with results from Corriveau and Harris (2010) who devised an Asch paradigm for children to study social conformity and observed that young children conform to social norms less frequently than usually adults do. It is possible that it is only with aging that children become increasingly aware that PEBs bear the normative weight of collective appreciation, at least at the level of manifest attitudes (Avery & Butera, 2022) to which they feel pressured to conform. We could assume that older children's scores on self-reported PEB questionnaires are biased to a greater extent in an upward direction than those of younger children. This bias would result in minimizing the differences between a treatment and a control condition or the difference between a pre-test and a post-test, therefore underestimating the effect size. Since the self-reports were the most prevalent kind of instrument in the meta-analysis, this could account for the negative correlation between age and intervention effect size. Finally, it cannot be excluded that van de Wetering et al. (2022) did not find this relationship because of different methodological choices in study inclusion or coding decisions that biased some of the estimated effect sizes.

Contrary to our predictions, interventions' effectiveness was found to be substantially greater when PEBs were assessed with actual, behavioral measures (field and laboratory observations) rather than with self-reports. External observations seem better suited to tackle immediate differences in behaviors caused by interventions compared to self-reports. On top of the social desirability bias mentioned above, past research suggested that self-reports are suboptimal to assess immediate effects by an intervention because of the limited time laps in between where an actual change in behavior could occur (Lange & Dewitte, 2019). Finally, an alternative possibility to account for such an important disparity between self-reported and actual PEB measurements could be the publication bias. Our post-hoc analyses (see Supplementary Information 5) revealed that in all the papers where there was a single outcome, PEBs were assessed as either field or laboratory observations, whereas papers where self-reports were used included also other outcome variables (e.g., attitudes, knowledges …). Despite our call for unpublished data, such an overlap highlights the risk that studies that used field or laboratory observations and were not significant ended up being unpublished (Maxwell, 2004).

4.2. Limitations

This meta-analysis focused on immediate effects and did not include follow-up effects. This begs the question as to what extent the impact of the interventions is persistent and stable over time, and whether some interventions are better than others with this respect. It is widely acknowledged that educational intervention effects are prone to *fade-out* such that their strength diminishes or disappears over time (Bailey et al., 2020). It remains unclear if the same holds true in the case of interventions conducted in experimental settings such as those included here. Addressing this issue constitutes both a challenging and fascinating direction for future research. With this respect, Bailey et al. (2020) discussed practical implications for designing interventions with children to assess the extent of fade-out effects.

4.3. A research agenda to study PEB promotion with children

4.3.1. Promote Research Diversification

More research is needed to study the promotion of PEBs with children, but what kind of research should be promoted? We propose that future research should focus on diversifying the field at the theoretical and methodological level, by drawing from approaches complementary to environmental education. Both theoretical and empirical arguments presented here make the case for the usefulness of interventions designed to change children's behaviors through social influence. Additive processes interventions also serve as examples of successful applications of other promising frameworks, such as social cognitive theory (Boudet et al., 2016; Cornelius et al., 2014). However, interventions should be carefully designed so to enable drawing unambiguous causal inferences with respect to the targeted theoretical factors responsible for changes in observed behaviors (Harackiewicz & Priniski, 2018). Such intensification of research will allow future meta-analyses to compare the various methods used in the literature with more statistical power than what the present research could do. This may result in two important possible outcomes: (a) It will be possible to compare the relative efficacy of the various interventions used, which may inform practitioners and policy makers on best practices; (b) it will be possible to compare the relative effectiveness of interventions with children to the relative effectiveness of interventions with adults, thereby making it possible to develop differentiated strategies of policy making.

4.3.2. Develop validated self-report scales

Not only most of the available literature relies on self-reports to measure children's PEBs, but only a handful of studies used published scales with established psychometric validity. Exploratory analyses indicated that among studies that employed self-reports, around 80% used either adaptations of published materials or *ad hoc* instruments (see Supplementary Information 3). This means that published instruments are not well suited to researchers' needs studying children's PEBs. Future research should address this gap and develop new scales adapted to children's language abilities with a broad relevance of their PEBs, including energy conservation behaviors, littering, recycling, and responsible actions towards nature. We acknowledge that factors such as time constraints, development costs and ethical issues inherent to research on children may impede the development and validation of such scales. However, we strongly encourage the broader scientific community, including authors, but also reviewers and editors, to recognize the scientific utility of the efforts.

4.3.3. Study observable behaviors

Future research should focus on designing interventions that include observable behaviors. Ensuring methodological diversity is vital and particularly stands out in environmental education research where field and laboratory observations are currently anecdotal (see Supplementary Table 2). Summer or nature camps offer opportunities for easy and low-cost implementations of field observations (Bexell et al., 2013). Classroom interventions may implement laboratory observations of PEBs involving decision making tasks or situations (Baur & Haase, 2015; Ebersbach & Brandenburger, 2020; Hadjichambis et al., 2015). Finally, children's PEBs could be also studied at home in collaboration with parents (e.g., Mahasneh et al., 2017), provided the former are not confounded with adults' behaviors. Such studies may contribute to rule out or, on the contrary, highlight the possible effects of social desirability discussed above in relation to self-report measures.

4.3.4. The earlier the better

The meta-analysis revealed a negative correlation between age and intervention effectiveness. More research is needed to clarify the reasons that account for this relationship, and we have speculated on possible developmental, normative, and methodological factors. These factors will need to be disentangled in future research. However, if the effect of age turns out to be generalizable, the implications of the present results are straightforward at the practical level: The promotion of pro-environmental behaviors will be best achieved the sooner it occurs in children's socialization and education processes.

4.3.5. Study group effects

Exploratory analyses showed that the majority of interventions studied children who participated in groups (see Supplementary Information 3). The Social Identity Model of Pro-Environmental Action by Fritsche et al. (2018) argues that PEBs proceed from group processes, in that environmental issues, problems and crises (1) may only be fully understood if represented as collective phenomena (they result from the joint action of billions of people), and (2) may only be acted upon if one's action can be represented as coordinated with that of others (no single person can have an impact of the environment). Therefore, we believe that future interventions promoting PEBs in children should capitalize on the group dynamics that might emerge in such settings, such as social identity, social norms, cooperative learning, help-seeking behaviors and the development of collective efficacy.

4.3.6. Publish non-significant results

Given the suspicion of publication bias regarding the studies involving field or laboratory observations of PEBs in particular (see Supplementary Information 5), we strongly encourage researchers to publish their results, irrespective of statistical significance and journal editors to welcome papers failing to confirm effectiveness of interventions. It might seem an out-of-fashion recommendation, but the dissemination of non-significant findings of properly conducted studies is vital and has become part of canonical research standards (Nosek et al., 2015). Embracing open-science practices such as the preregistration of hypotheses, designing well-powered studies, accurate reporting of statistical information (i.e., means, standard-deviations, sample sizes, pre-post correlations) and making data available online will substantially help in the future meta-analytical endeavors (Jonas & Cesario, 2016).

Data availability statement

Data, the R Code necessary to conduct the analyses, the excel files with search and screening outputs and details on effect size computations can be found in Supplementary Online Material available at https://osf.io/rq8na/.

CRediT authorship contribution statement

Wojciech Świątkowski: Conceptualization, Data curation, Formal analysis, Methodology, Project administration, Writing – original draft, Writing – review & editing. **Fantine Lisa Surret:** Methodology, Writing – review & editing. **Johanna Henry:** Data curation, Methodology. **Céline Buchs:** Funding acquisition, Writing – review & editing. **Emilio Paolo Visintin:** Funding acquisition, Writing – review & editing. **Fabrizio Butera:** Conceptualization, Data curation, Methodology, Project administration, Supervision, Writing – original draft, Writing – review & editing, Funding acquisition.

Declaration of competing interest

We have no known conflict of interest to disclose.

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Supplementary information

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