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SHORT REPORT

# Slow tempo music preserves attentional efficiency in young children

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**Abstract**

Past research has shown that listening to slow- or fast-tempo music can affect adults' executive attention (EA) performance. This study examined the immediate impact of brief exposure to slow- or fast-tempo music on EA performance in 4- to 6-year-old children. A within-subject design was used, where each child completed three blocks of the EA task after listening to fast-tempo music (fast-tempo block), slow-tempo music (slow-tempo block), and ocean waves (control block), with block-order counterbalanced. In each block, children were also asked to report their pre-task subjective emotional status (experienced arousal and valence) before listening to music and their post-task emotional status after the EA task. Three major results emerged. First, reaction time (RT) was significantly faster in the slow-tempo block than in the fast-tempo, suggesting that listening to slow-tempo music preserves processing efficiency, relative to fast-tempo music. Second, children's accuracy rate in the EA task did not differ across blocks. Third, children's subjective emotional status did not differ across blocks and did not change across the pre- and post-task phases in any block, suggesting the faster RT observed in the slow-tempo block cannot be explained by changes in arousal or mood.

**Keywords** Tempo · Executive attention · Emotional state · Music · Reaction time · Young children · Cognitive performance

## Introduction

Tempo communicates the pace of a piece of music and can affect listeners' decoding of the emotional meaning of music (e.g., Ilie & Thompson, 2006; Juslin & Laukka, 2003) and can impact their affective experience (e.g., Ilie & Thompson, 2011; Schellenberg, 2006), with fast-tempo related to high arousal and positive moods, and slow-tempo associated with low arousal and negative moods (Husain et al., 2002; Thompson et al., 2001). Exposure to slow and fast tempo music may also have cognitive effects, but the evidence for such effects is uncertain. Although exposure to fast tempo music can lead to increased arousal states that are, in turn, associated with increased speed of processing (Duffy, 1972; Ilie & Thompson, 2011; Thompson et al., 2001), fast tempo and positively valenced music may also hinder executive attention performance (McConnell & Shore, 2011) while fast and loud background music can disrupt reading comprehension (Thompson et al., 2011). The goal of this investigation was to determine whether brief prior exposure to slow- or fast-tempo music can affect 4- to 6-year-olds' executive attention (EA) performance, and whether such effects can be attributable to changes in arousal and/or mood.

EA refers to an individual's ability to concentrate on targets and ignore distractors, which is essential for learning and cognitive development (e.g., Engle, 2002). Rueda et al. (2004) found that children's EA improved from age 6 to age 7 years, as indicated by 7-year-olds' faster and more accurate EA performance. In addition, children's EA performance became adult-like around 10 years of age. However, Rueda et al. did not investigate 4- to 6-years' EA performance, leaving a gap in our understanding of the early development of EA. To fill this gap, this study examined EA in 4- to 6-year-olds.

Why does musical tempo affect attentional performance in children? One possibility, referred to as the *mood-arousal hypothesis*, is that music impacts upon arousal and mood states, which in turn, affect cognitive performance (Husain et al., 2002; Nantais & Schellenberg, 1999; Steele, 2000; Thompson et al., 2001). In addition, the broaden-and-build

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theory states that when people are in a positive emotional state, the scope of their attention is broadened, and they are consequently more likely to be misled by distractors (LeBlanc et al., 2015; McConnell & Shore, 2011). As fast tempo music can elicit positive moods (Edworthy & Waring, 2006), it might enhance listeners' global information processing, making them less likely to ignore task-irrelevant stimuli.

Another possibility is that exposure to musical tempo can directly impact attention independently of any effects on arousal and mood (Amezcua et al., 2005; Baldwin & Lewis, 2017; Li et al., 2019). For example, external rhythms may confer general cognitive benefits because their predictability conserves processing resources (Schirmer et al., 2021). The degree of conservation may depend on the pace of the external rhythm, with slow-tempo music likely to conserve processing resources more effectively than fast-tempo music. In addition, according to the attentional restoration theory, a restorative environment may allow fatigued individuals to rest their internal mechanisms and replenish their attentional resources (Baldwin & Lewis, 2017). Baldwin and Lewis reported that slow-tempo music might provide such a restorative environment, and thereby support attentional performance. However, these studies focused on adult listeners, rather than the effect of musical tempo on children's attentional performance.

Research has yet to examine the independent impact of musical tempo on young children's attentional performance. Findings on the Mozart effect in children are relevant, but mixed (Črnčec et al., 2006; Hui, 2006; Schellenberg et al., 2007). Whereas some research showed that listening to an up-tempo piece of Mozart music in comparison to a slow piece of Albinoni Mozart facilitated 5-year-olds' drawings in terms of creativity and energy (Schellenberg et al., 2007), other evidence suggests that listening to a piece of Mozart music in comparison to popular music and silence did not enhance children's spatiotemporal performance (Črnčec et al., 2006; Hui, 2006). Furthermore, it should be noted that the Mozart music, popular music, and silence used in these studies differed from each other in various acoustic attributes beyond tempo, leaving children's sensitivity to tempo unclear.

Despite these ambiguities, developmental evidence confirms that children are sensitive to tempo. Dalla Bella et al. (2001) found that 5-year-old children could use tempo as a cue to distinguish between happy and sad Western classical music. In addition, children can describe music as fast or slow from age 3 years (Schubert & McPherson, 2006). These findings open up the possibility that prior exposure to slow- or fast-tempo music may affect EA performance in young children.

Two important questions remain: (a) does listening to fast- and slow-tempo music affect children's attentional performance? If so, (b) is the attentional effect of musical tempo dependent on its effect on children's arousal and mood. To address these questions, the current investigation aimed to determine whether 4- to 6-year-old children's EA performance increased after listening to slow-tempo music rather than fast-tempo music, and whether the effect can be explained by changes in arousal and/or mood. Based on the theories mentioned above, it was hypothesized that: (a) fast-tempo music should enhance children's arousal and mood, which broadens their scope of attention and thus hinders EA performance; (b) slow-tempo music should provide a restorative environment and conserve processing resources, thereby enhancing EA performance.

## Materials and methods

### Participants

To determine an optimal sample size, a power analysis was conducted using G*Power 3.1.9.7 (Faul et al., 2009) for repeated-measures analysis of variance with power = .80, p = .05 and an expected effect size (f) = .25. The analysis indicated that a minimum of 28 participants was required. The final set of participants consisted of 31 4- to 6-year-old (*M* = 61.16 months, range = 48–76 months; 17 males) children from Hong Kong and Shenzhen China. They voluntarily participated in the experiment and were recruited from three kindergartens by the first author of this article. Three additional children were initially recruited but excluded from the final sample because their mean accuracy rate in the EA task was lower than 65%.

### Auditory stimuli

This study used a piano version of "Do-Re-Mi" from The Sound of Music, because young children are more likely to use tempo as a cue to identify emotions in simple and familiar song (Dalla Bella et al., 2001; Mote, 2011). The original film version had a tempo that gradually increased from roughly 120–130 beats per minute (bpm). Audio Retoucher (AbyssMedia, 2016) was used to modulate its tempo, with the fast-tempo and slow-tempo versions having 160 and 66 bpm, respectively. Ocean wave sound – rather than silence – was used as the control, because like music, natural sounds may be pleasant to listen to, and have emotional connotations (Ma & Thompson, 2015). Ocean wave sounds are also rhythmic, enabling us to determine whether any effects of tempo on EA performance are specific to music. The duration of the fast, slow, and control excerpts were 58, 66, and 52 s, respectively. These durations were adopted because they are neither too short to induce an effect nor too long to make children bored. Previous research has confirmed that 41-s to 1-min emotional music can impact story interpretations in 5- to 6-year-olds (Ziv & Goshen, 2006), confirming that music duration of this length is viable for this age group.

## Executive attention task

This study used the EA component of the child version of the Attention Network Test (Rueda et al., 2004). Each trial started with the presentation of a fixation cross in the center of the display area which remained for 1,000 ms. Then, the target array – consisting of five orange fish arranged horizontally on a blue background – was presented and remained until a response was made. Children were asked to indicate the direction of the fish in the middle (the central fish) by pressing the corresponding key on a keyboard as quickly and accurately as possible ("J" – facing the right; "F" – facing the left). There were two types of trials. On the congruent trials, the central fish faced the same direction as the other four fish. On the incongruent trials, the central fish faced the opposite direction in relation to the other four fish (Fig. 1).

## Emotion

Schematic faces were used to assess children's subjective emotion, since pointing to schematic faces was widely used to measure children's emotional responses to music and speech (Dalla Bella et al., 2001; Ma, Tao et al., 2017; Ma, Zhou et al., 2022; Schubert & McPherson, 2006). Two dimensions of emotion were considered – arousal and valence. Schubert (2004) concluded that an upward mouth represents positive valence and a downward mouth represents negative valence; a larger eye shape indicates higher arousal. Thus, five schematic faces were chosen from a popular emoji package (Fig. 1). In the valence dimension, they stand for happy, neutral, and sad; in the arousal dimension, they stand for calm, neutral, and excited, respectively, from left to right. Children's tasks were to choose their subjective emotions at that moment by pointing to one schematic face from each dimension.

## Procedure

Children were tested individually by the first author of this article in a quiet room at their preschool. Each experiment started with a task familiarization phase. Children were asked to recognize five schematic emotional faces and complete seven practice trials of the EA test (three congruent trials and four incongruent trials). All children were correct on emotional face recognition and the practice trials, confirming that they had little difficulty with the task. The test phase contained three blocks – the fast-tempo, slow-tempo, and control blocks (Fig. 1). In each block, children (1) reported their pre-task subjective emotional states (valence and arousal), (2) listened to an auditory stimulus (fast or slow music, or ocean waves), (3) completed an EA task – 12 incongruent trials and 12 congruent trials presented in random order, and (4) reported their post-task emotional status. After each block, there was an average 20-s break when children were asked to count numbers to distract their attention from the EA task. The presentation order of the three blocks was counterbalanced across participants. The experiment was completed through the E-prime 2.0 on a 14-in. computer. The auditory stimuli were presented to the participants through a high-quality stereo over-ear headphone. Each experiment lasted for approximately 20 min.

## Data analysis

**Individual data pre-processing** For each participant, a mean accuracy rate was calculated within each block. The RT analysis – with the incorrect responses to the EA task (4.9% of the total) excluded – followed the trimmed mean procedure outlined by McConnell and Shore (2011) for RT data with a strong positive skew, as found in our study. For each child, the top and bottom 10% of the data were removed when calculating the trimmed mean RT for the 12 congruent trials and the 12 incongruent trials.

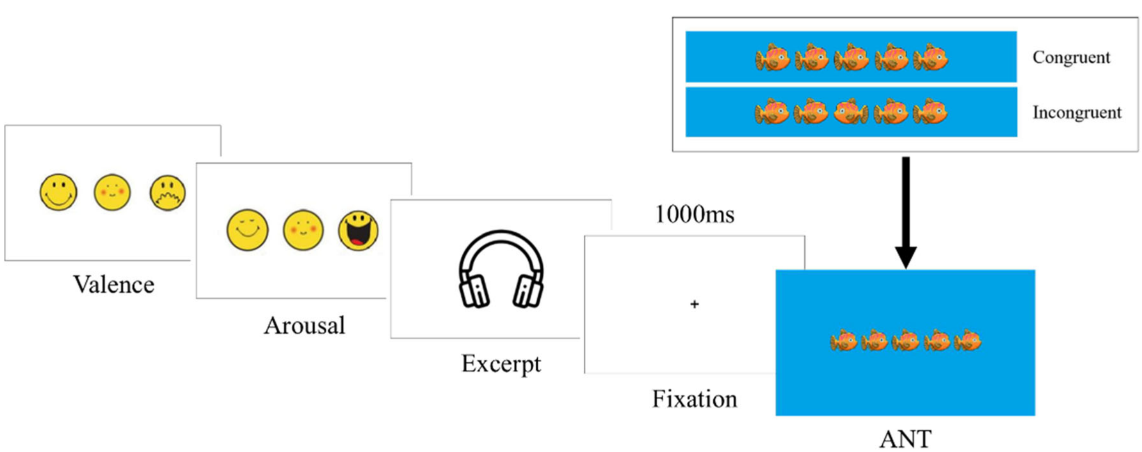


**Fig. 1** The stimuli and experimental procedure used in this study. The post-task subjective emotional status report was identical to that of the pre-task

**Group data** Shapiro-Wilk tests showed that the mean accuracy rates and trimmed mean RT in both congruent and incongruent trials violated the normal distribution assumption (*p*s < .02). Thus, non-parametric tests were used in data analysis.

## Results

**Reaction time** Table 1 displays descriptive data of trimmed mean RT and accuracy rates across the three blocks. A Friedman test – the nonparametric one-way repeated-measure analysis – indicated that RT differed across the three blocks on incongruent trials ($\chi^2(2) = 7.16$, $p = .028$, Kendall's $W = .12$, $CI = [.03, .34]$), but did not differ on congruent trials ($\chi^2(2) = 1.61$, $p = .45$, Kendall's $W = .03$, $CI = [.00, .18]$). Post hoc analyses were conducted through Conover's all-pairs comparisons tests, with p-value adjusted by the Bonferroni correction method. On incongruent trials (Fig. 2), RT in the slow-tempo block (*Mdn* = 1,627 ms) was significantly faster than that in the fast-tempo block (*Mdn* = 1,835 ms, $p = .029$). Though there was no statistical difference between slow-tempo and control blocks ($p = .77$), the medians showed a trend that RT in the slow-tempo block was faster than that in the control block (*Mdn* = 1,853 ms). RT did not differ between the fast-tempo and control blocks ($p = .39$).

**Accuracy rate** A Friedman test found that accuracy rate did not differ across the three blocks on either congruent trials ($\chi^2(2) = .34$, $p = .84$, Kendall's $W = .006$, $CI = [.001, .14]$) nor incongruent trials ($\chi^2(2) = 1$, $p = .61$, Kendall's $W = .02$, $CI = [.002, .16]$). A ceiling effect for accuracy emerged (see Table 1).

**Subjective emotional status** Table 2 displays the number of participants who rated each dimension of experienced emotion before and after listening to music. McNemar Chi-squared tests – test on paired nominal data – indicated no difference between pre- and post-subjective emotional states across the three blocks. McNemar Chi-squared tests on child post-task emotional status showed that neither arousal nor valence differed across any of two blocks.

**Table 1** Medians and range of trimmed mean reaction time and accuracy rate in the three conditions on congruent and incongruent trials

| Condition | Reaction time (ms) | Accuracy rate |
|---|---|---|
| Congruent trials | | |
| Fast tempo | 1,819 (988–4,479) | 1 (.75–1) |
| Slow tempo | 1,574 (656–3,417) | 1 (.75–1) |
| Control | 1,671 (1,062–3,378) | 1 (.67–1) |
| Incongruent trials | | |
| Fast tempo | 1,835 (1,172–5,711) | 1 (.71–1) |
| Slow tempo | 1,627 (845–4,042) | 1 (.58–1) |
| Control | 1,853 (1,050–4,375) | 1 (.67–1) |

## Discussion

This study examined the effect of prior exposure to slow- and fast-tempo music on 4- to 6-year-olds' EA performance. Accuracy in EA was unaffected by prior exposure to music, but the high accuracy rates suggest there was a ceiling effect for this task. However, listening to slow-tempo music preserved processing efficiency, as indicated by faster RT data for this condition than the fast-tempo music condition on incongruent trials. This finding also confirmed that children were sensitive to differences in tempo, ruling out the possibility that the lack of difference in accuracy across conditions reflected insensitivity to tempo. Finally, subjective emotional status did not differ across blocks or between the pre- and post-task phases within any block, demonstrating that the faster RT observed in the slow-tempo block cannot be explained as an arousal or mood effect.

Why does listening to slow-tempo music preserve RT, compared to fast-tempo music? As proposed by Schirmer et al. (2021), external rhythms can confer cognitive benefits because their high predictability conserves processing resources. Moreover, the degree of conservation provided by music may also depend on the pace of the external rhythm, with processing resources preserved more effectively by slow-tempo than fast-tempo music. Listening to fast-tempo music, though predictable, may consume or deplete attentional resources for young children, hindering the allocation of attentional resources towards the EA task. Slow-tempo music probably provides a restorative environment that may replenish attentional reserves and hence facilitate the latter task performance. This interpretation is compatible with the evidence that prior exposure to slow and positive music promoted participants' executive control over sustained attention (Baldwin & Lewis, 2017).

This investigation revealed that listening to slow-tempo music preserved RT on incongruent trials, but not congruent trials. One interpretation of this result is that incongruent trials were more cognitively demanding, and the benefits of slow-tempo music on RT requires a task that is cognitively demanding. In general, listening to slow-tempo music may not benefit RT when the task is too easy (when cognitive assistance from slow-tempo music is redundant) or too difficult (when cognitive assistance from slow-tempo music is ineffective). Another possibility, however, is that the fast-tempo version of the song activated associations such as autobiographical memories (Castro et al., 2020), either because it enhanced arousal or was more familiar. Music-evoked associations, in

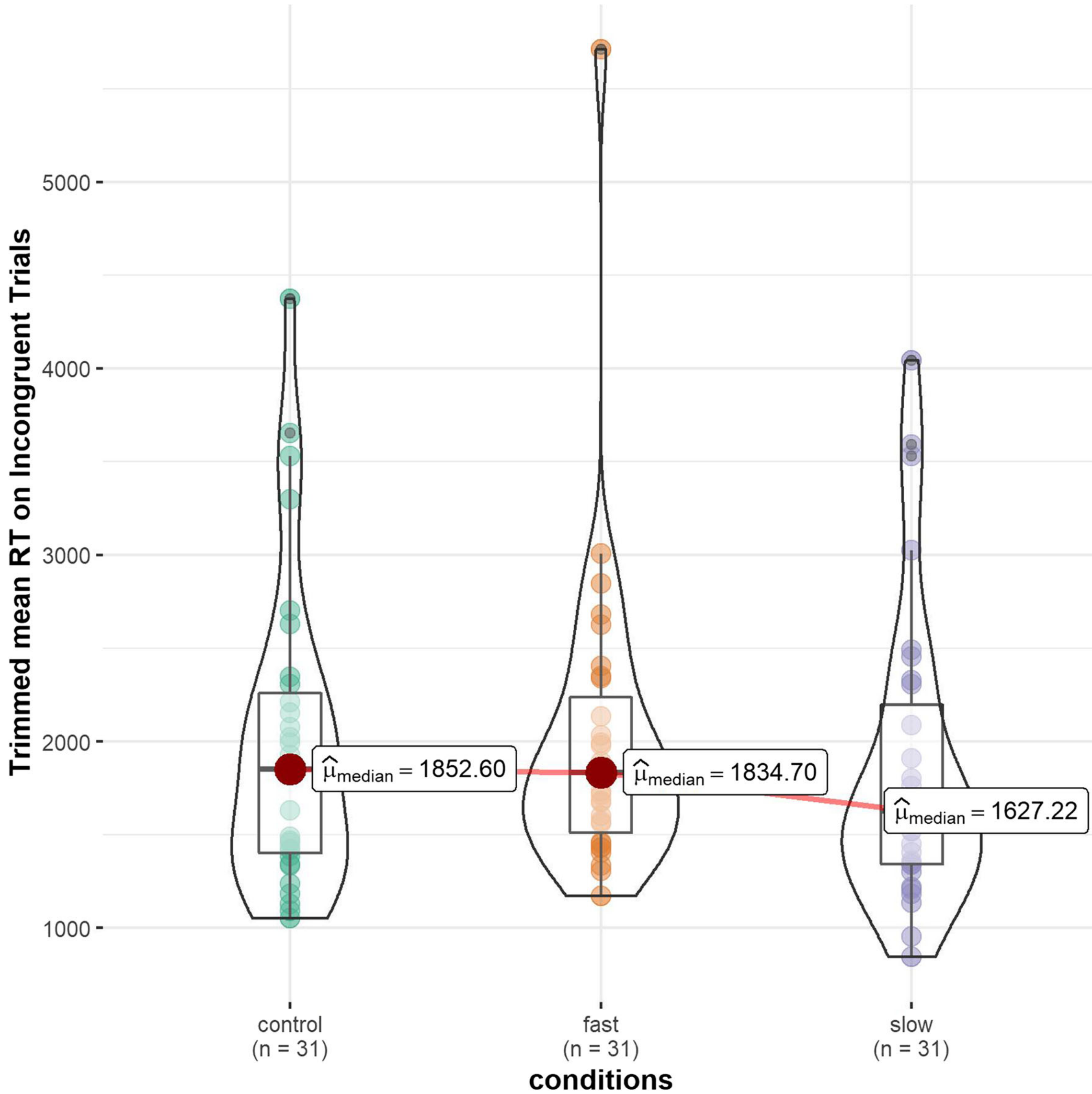


**Fig. 2** Violin plot of trimmed mean reaction time (RT) on incongruent trials by conditions

**Table 2** Number of participants rating of experienced arousal and valence in the before- and post-task phases

| | Before-task | | | Post-task | | |
|---|---|---|---|---|---|---|
| Conditions | Fast-tempo | Slow-tempo | Control | Fast-tempo | Slow-tempo | Control |
| Experienced arousal | | | | | | |
| Calm | 7 | 6 | 7 | 9 | 8 | 7 |
| Neutral | 13 | 13 | 13 | 10 | 12 | 13 |
| Excited | 11 | 12 | 11 | 12 | 11 | 11 |
| Experienced valence | | | | | | |
| Sad | 3 | 4 | 3 | 4 | 2 | 2 |
| Neutral | 11 | 7 | 11 | 10 | 11 | 12 |
| Happy | 17 | 20 | 17 | 17 | 18 | 17 |

turn, may have distracted children from the task at hand, hindering performance. Future research should examine the various ways that arousal, familiarity, and task difficulty may interact with the impact of slow-tempo music on attentional efficiency.

Why did tempo affect children's RT but not their accuracy rate? The most likely explanation is that there was a ceiling effect for accuracy, with 95–96% accuracy rates in all three conditions. To evaluate this interpretation, future research should investigate the effects using more challenging measures of child EA. A second interpretation is that RT and accuracy are associated with different mechanisms, as suggested by past research (Prinzmetal et al., 2005). More generally, RT is a more sensitive indicator to the tempo effect than accuracy rate. Thus, a significant effect on accuracy may require a stronger manipulation of tempo than was presented in the current design. Notably, the arousal and mood hypothesis (e.g., Schellenberg, 2012; Thompson et al., 2001) predicts that any change in cognitive performance should be accompanied by corresponding changes in arousal and valence (mood), but this was not the case in our investigation.

Past research suggests that by the age of 5 years, children start to reliably decode the emotional meaning of tempo in instrumental music (Dalla Bella et al., 2001) and in song at ages 4–5 years (Mote, 2011), but we observed no differences in children's subjective emotion ratings across blocks. Quite possibly, longer exposure to music is required for children to feel changes in their arousal or mood than for children to decode emotional meaning in music. It is also possible that the ability to feel a music-evoked emotion develops later. Additionally, it is possible that the "game" environment employed in the current investigation increased children's subjective arousal and valence to a level that overwhelmed any effects of listening to music. Indeed, children in this study were enthusiastic about their participation, and were unlikely to rate their emotional status as low-arousal (calm) or low-valence (sad) regardless of what they heard. Future research can use physiological measures to assess children's experienced emotion, to validate and extend the current finding.

This study suggested that prior exposure to slow-tempo music in 4- to 6-year-old children led to a significant decrease in RT on incongruent trials of an executive attention task, compared to exposure to fast-tempo music. A trend that RT was faster in slow-tempo than in a control condition was also found. The effect was not associated with children's experience of arousal and mood. There may be a link between the pace of external rhythm and attention performance. A slow external rhythm might conserve and restore attentional processing resources with its high predictability and low variability.

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**Open practices statement** None of the data or materials for the experiments reported here are available, and none of the experiments were preregistered.

**Authors' contributions** YQ designed the study, conducted the experiment, and organized the data. WM performed the data analysis and wrote this manuscript. HL contributed to the conception of the study. WT provided comments on the manuscript and revised it critically. All authors approved it for publication.

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**Data availability** Data that support the findings of this study are available from the corresponding author upon request.

**Code availability** Not applicable.

## Declarations

**Conflicts of interest** The authors have no relevant financial or non-financial interests to disclose.

**Ethics approval** All procedures performed in this study was approved by the Human Research Ethics Committee of the University of Hong Kong.

**Consent to participate** Written informed consent to participate in this study was obtained from the participants' legal guardian and principals of the three kindergartens beforehand. Verbal informed consent was obtained from all child participants prior to the experiment.

**Consent to publication** Not applicable. All data have been stored in de-identified form as numeric values only. No words, images, or videos of individual participants were collected in the investigation.

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