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Does active school travel improve mood and academic functioning? A within-person study among adolescents

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Abstract

Active school travel, walking or cycling to school, may contribute to daily physical activity, with well-established benefits for physical health. Active travel has also been associated with better mood and cognitive performance, but whether these associations reflect effects of active travel itself remains uncertain. Most existing studies rely on cross-sectional designs that cannot distinguish the effects of travel mode from pre-existing individual differences. We use a repeated-measures field design to examine whether adolescents' mood and cognitive functioning differ across days when they travel actively versus passively to school. Students aged 13–16 from two Norwegian lower-secondary schools participated in up to four survey rounds over two weeks (468 students; 1,116 observations). Schools sent pre-specified messages encouraging active or passive travel, generating within-person variation in travel behaviour. Outcomes measured shortly after school-arrival included mood, self-reported performance, working memory, and executive functioning. Among students who changed travel mode in line with the instructions, active-travel days involved approximately 13–15 additional minutes of active transport. Despite this meaningful change in travel behaviour, we found no consistent improvement in mood, self-reported performance, working memory, or executive functioning on active-travel days. The findings were confirmed by a difference-in-difference approach comparing students who changed their travel mode in line with the instructions (compliers) with those who maintained their usual mode (non-compliers), to control for time-varying confounds common to both groups. The findings suggest that the immediate psychological benefits of active travel may be weaker, more context-dependent, or less universal than is often assumed.

Keywords: active school travel; adolescents; mood; academic functioning; cognitive performance.

1 Introduction

For children and adolescents, travelling to school by foot or bike represents one of the few forms of physical activity that can be embedded into everyday routines. Therefore, active school travel can be an important contributor to daily physical activity Hillman et al. (1990); (Larouche et al., 2014; van Sluijs et al., 2021), which in turn may support mood and cognitive function (Buecker et al., 2021). As the school commute represents a daily transition into the learning environment, a key question is thus whether the way students travel to school shapes how they feel and think once they arrive. Using a within-person approach with exogenous travel mode cues, this paper examines whether adolescents' mood and self-reported performance differ on days when they travel by foot or bike to school compared to days when they do not.

An increasing literature documents that regular participation in physical activity may support aspects of cognitive functioning and classroom engagement in children (Donnelly et al., 2016; Lubans et al., 2016). Moreover, a substantial body of research demonstrates that physical activity is associated with improved subjective well-being (Buecker et al., 2021). Regarding academic achievement, however, the evidence is less consistent (Walker & Gamble, 2023).

A smaller, yet growing body of research has examined whether active travel also yields positive benefits in these domains. Several studies report that children who walk or cycle to school experience higher levels of travel satisfaction during the journey compared with

those travelling by passive modes (Friman et al., 2018; Stark et al., 2018; Stark et al., 2019; van den Berg et al., 2020). Other studies have found associations between active school travel and indicators of psychological well-being or life satisfaction (Frömel et al., 2020; Khaleghi & Kato, 2023; Wu, 2025). Evidence also suggests that school travel mode may be related to children's academic achievement and psychological well-being (Ding & Feng, 2022). Similar patterns have been observed in the literature on everyday travel behaviour among adults, where active commuting has been associated with lower commuting stress, improved mental health indicators, and higher life satisfaction (Liu et al., 2021).

Much of the existing literature focuses on the cumulative effects of physical activity, that is, the benefits that build up through sustained activity over time. However, in recent years there has been increasing interest in the more immediate impacts of physical activity. Studies of affect in children and adolescents suggest that physical activity may be followed by short-term improvements in positive affect and energy, although findings are less consistent for negative affect and mood (Bourke et al., 2021, 2023; Yang et al., 2021). Similar interest in immediate effects is evident for cognitive performance. Comparing performance on cognitive tasks before and after a single bout of exercise, studies have reported small but consistent improvements in attention, inhibitory control, and processing speed (Chang et al., 2012). Evidence from school-based interventions is less consistent, with several reviews reporting limited or null effects of single exercise bouts on cognitive outcomes, while longer-term participation appears more reliably associated with

improvements in domains such as working memory (Donnelly et al., 2016; Singh et al., 2012).

This discrepancy may reflect differences in both context and measurement. Acute effects of physical activity are likely to be modest and short-lived, and therefore difficult to detect in real-world settings using broad or distal outcome measures such as grades or general academic attainment. In addition, many studies rely on retrospective or global assessments of well-being and functioning, which are not well suited to capturing momentary changes in affective and cognitive states. Approaches such as experience sampling methods (ESM), which capture individuals' states in real time or close to the moment of experience (Csikszentmihalyi & Larson, 1987), may therefore provide a more sensitive means of detecting such short-term effects in everyday contexts (Bourke et al., 2021, 2023).

Most existing studies in the impact of active school travel literature rely on cross-sectional comparisons between children who typically travel actively and those who use passive modes (Ding & Feng, 2022; Friman et al., 2018; Stark et al., 2018).

Such designs cannot distinguish effects of travel mode from pre-existing differences between students. Using within-person variation in daily travel, (Fyhri et al., 2023) found that active commuting was associated with more positive mood shortly after the journey among adults. Whether similar short-term associations exist among adolescents travelling to school remains unclear.

A related limitation concerns measurement: long recall periods are poorly suited to capturing psychological states following a specific school journey, while studies of school-related outcomes have often relied on subjective indicators rather than objective cognitive tests (Ding & Feng, 2022). Objective assessments of cognitive performance are used less consistently. In this regard, executive functions are of particular interest. These refer to a group of mental processes needed when one has to concentrate and pay attention, including inhibition, working memory, and cognitive flexibility (Diamond, 2013). Meta-analytic evidence shows that a single bout of moderate aerobic exercise yields small but reliable improvements in executive function (Chang et al., 2012; Ishihara et al., 2021; Ludyga et al., 2016). Active travel may constitute such an acute bout of physical activity, making executive function a particularly relevant outcome when examining the immediate effects of travel to school.

Most evidence on active school travel and psychological outcomes relies on between-person comparisons, making it difficult to isolate the effects of travel mode. We address this limitation by comparing outcomes within the same students across active and passive travel days.

1.1 Aim and research question

The aim of the present study is to provide a stronger test of the causal relationship between active school travel and short-term psychological outcomes than has been possible in previous observational studies. Using repeated within-person measurements and

externally provided travel-mode cues, we examine whether active travel leads to differences in mood, self-reported performance, and cognitive performance.

More specifically, the study investigates the following hypotheses:

H1: Adolescents' mood upon arrival at school is better on days when they have travelled using active modes compared with passive modes.

H2: Adolescents' self-reported performance (e.g., concentration, working memory and executive functioning) upon arrival at school is better on days when they have travelled using active modes compared with passive modes.

H3: The observed differences in mood and self-reported performance can be attributed to active travel.

2 Data and methods

2.1 Procedure

We recruited students from two lower-secondary schools in Fredrikstad municipality, Norway. All students in grades 8–10 (ages 13–16) were invited. Participation was voluntary and anonymous and did not require parental consent. Data was collected by repeating the same survey four times over two weeks. The survey was completed during morning lessons. To be able to merge the surveys, while preserving anonymity, each student was

assigned a user login, a combination of a colour, adjective and animal, that they needed to enter to sign into subsequent surveys.

To induce travel-mode variation, the schools sent messages to students and parents the week prior to the data collection requesting students to choose active (S1 and S4) or passive (S2 and S3) modes of transport to school if possible. In addition, a message reminding them about the desired mode of transport was sent the day prior to each survey. The messages were distributed to parents and students using the school's standard communication platform.

The information for the active days was:

"Tomorrow, we want as many students as possible to walk or cycle to school. If distance is too long, it would still be nice if you could walk or cycle part of the distance."

The information for the passive days was:

"Tomorrow, we would like as many students as possible to travel by escooter, car or public transport to school. Feel free to coordinate with others so that more students can share the same car."

2.2 Sample

Table 1 presents the number of responses to each survey with a total of 1,116 observations. In total, 468 unique individuals participated in the study: 31 percent completed only one round, 21 percent two, 27percent three and 21 percent all four. The table also shows the share using active transport in each survey round.

Table 1 Overview of the number of respondents in each survey, and share using active transport.

Survey	Timing	Requested mode	Number of respondents	Share using active transport
S1	Week 1	Active transport	387	59%
S2	Week 1	Passive transport	216	50%
S3	Week 2	Passive transport	250	40%
S4	Week 2	Active transport	263	52%
		N	1,116	

Table 2 summarises the background characteristics of the 384 students who participated in the first survey round, when these data were collected. The sample is approximately evenly distributed across genders, with 52 percent identifying as female. The vast majority (87%) reported owning a bicycle, and nearly half (46%) reported owning an escooter. The

average self-reported distance to school was 2.9 km, and 56% indicated that they typically walk or cycle to school during this time of year.

Table 2 Sample characteristics

	All
Grade level (%)	
8th grade	37.7
9th grade	29.4
10th grade	33.0
Female (%)	52.1
Free school ride (%)	28.8
Access to mode:	
Own a bike (%)	87.1
Own an e-bike (%)	5.7
Own an escooter (%)	45.9
Distance to school (minutes walked)	26.1
Distance to school (km)	2.9
Multiple homes (%)	19.6
Usual mode to school (%)	
Walk	21.4
Bike	34.3

Escooter	25.1
Public transport	10.8
Car	7.4
Other	1.1
Observations	385

2.3 Survey measures

The baseline survey (S1) included survey questions on mode of transport, current mood, self-reported performance, and background characteristics in addition to two tests of executive function. Completion time was approximately 10–15 minutes. The remaining three surveys were identical to the first, except that background questions were omitted. These surveys required approximately 8–10 minutes to complete. The main survey measures were travel mode, mood and self-reported performance.

When analysing day-level associations between travel mode, mood and perceived performance measures it is key to have measures that refer to a recent, time-restricted temporal window, rather than broad retrospective evaluations. Accordingly, the present study assesses both mood and performance with reference to the current day. Same-day assessments are better suited to capture everyday affective fluctuations while repeated measurements across rounds allow for examination of within-person variation over time

(Ciccone, Karlsen & Fyhri, 2026). To limit cognitive burden, we used brief, conceptually distinct items.

Travel mode: Students selected their main mode of travel to school that day from nine options (walk, regular bike, e-bike, e-scooter, school bus, public transport, car, light motor vehicle (moped, ATV) and other). If more than one mode was used, respondents were instructed to choose the mode they considered the primary mode.

Mood was measured with four items adapted from the six-item mood scale of Wilhelm and Schoebi (2007). Each item was introduced with "Today, I feel …", followed by the bipolar adjective pairs: tired–awake, content–discontent, full of energy–without energy, and relaxed–tense. Each item was presented as a slider with eight points, ranging from 0 (first adjective) to 7 (second adjective). The items span the three dimensions of the original scale: energetic arousal, valence, and calmness. The Norwegian translation of these items has previously been used in Ciccone, Karlsen & Fyhri (2026) and Fyhri and colleagues (2023).

Self-reported performance during the start of the school day was measured with three items adapted from Fyhri et al. (2023) introduced with "So far today, I think I am …": (1) "working efficiently"; (2) "easily distracted"; and (3) "concentrating well on my tasks". Each item was rated on a seven-point Likert scale from "completely disagree" to "completely agree". Item (2) was reverse-coded, and the three items were averaged into a single index.

We retained the wording of Fyhri et al. (2023), who applied the items to working adults, to allow comparison across settings.

2.4 Test measures

To investigate the relationship between active travel and executive function, the Stroop test and matrix monitoring task were used.

The matrix monitoring task

The matrix-monitoring task measures working-memory updating (Salthouse et al., 2003). Following Forman et al. (2011) participants tracked the position of a dot in a 4 × 4 grid as it moved according to a sequence of arrows, and then judged whether its final displayed position was correct. The task comprised nine trials: three each with three, four, or five arrows. The starting position and arrow sequence were randomised, and the initial grid and each arrow were displayed for 2,500 ms. The task was programmed in Qualtrics by Survey Awesome, with the final dot displayed no more than one cell from its correct position. The number of correct responses was used as the outcome measure.

The Stroop test

The Stroop colour-word test measures inhibitory control and selective attention (Homack & Riccio, 2004). We used the web-based version developed by Singh and Göritz (2018), implemented in Qualtrics following the JavaScript procedure documented Assinnari (2020).

Participants identified the display colour of four colour words (RED, GREEN, YELLOW, BLUE) by clicking the corresponding response button. The task comprised 50 randomly ordered trials, equally divided between congruent and incongruent word-colour combinations. Each stimulus remained visible until a response was given, followed by 500 ms of accuracy feedback. Following MacLeod (1991), median reaction time for correct responses on incongruent trials was used as the outcome measure.

2.5 Analytical approach

The data set is an unbalanced panel as not all individuals participated in all four survey rounds. For a substantial number of individuals (144) we only have one observation, which means that we lack the time dimension and thus the observations do not contribute to estimations when we condition on being observed on multiple days.

We start the analysis with within-individual pairwise t-test comparisons of outcomes on active instruction days and passive instruction days. The analysis is restricted to individuals who complied with instruction on the two days in question (compliers). As we have four survey rounds, two with an active instruction and two with a passive instruction, which gives us four comparisons. Two within-week comparisons (day 1 vs day 2 and day 3 vs day 4) and two across-week comparisons (day 1 vs day 3 and day 2 vs day 4). We always organise the results so that it is the active day less the passive day and positive (negative) differences imply that the observed outcome is higher on an active (passive) day.

Outcomes could be sensitive to the day of the week or repeated exposure to the same questions and tests, which in turn could influence the results of our within-person comparisons. To address this, we compare compliers to those who did not follow instructions (the comparison group), essentially adopting a difference-in-difference logic in which the comparison group is assumed to absorb time-varying confounds common to both groups.

The estimate of interest is:

$$\delta = (within\ person\ change, compliers) - (within\ person\ change, noncompliers),$$

where within-person change is defined throughout as the outcome on an active instruction day minus the outcome on a passive instruction day. A positive δ therefore indicates that compliers' outcomes improved (declined) relatively more (less) on active days compared to non-compliers over the same period.

We distinguish between three non-complier subgroups: those who chose an active mode in both survey rounds ("Active comparison"), those who chose a passive mode in both survey rounds ("Passive comparison") and those who switched mode in the opposite direction of instructions. The first two groups serve as the comparison group in the difference-in-difference estimation, the third is excluded from the analysis, as their behaviour is difficult to interpret relative to the counterfactual. In a robustness check we have found that separating between active and passive non-compliers yields similar estimates. As a result, we combine them for power and simplicity.

3 Results

3.1 Descriptive results

Figure 1 shows small differences in the expected direction across all four outcomes, but none are statistically significant (Table A1). As these comparisons do not account for differences between students, we turn to within-person analyses to examine whether active travel is associated with better mood and performance.

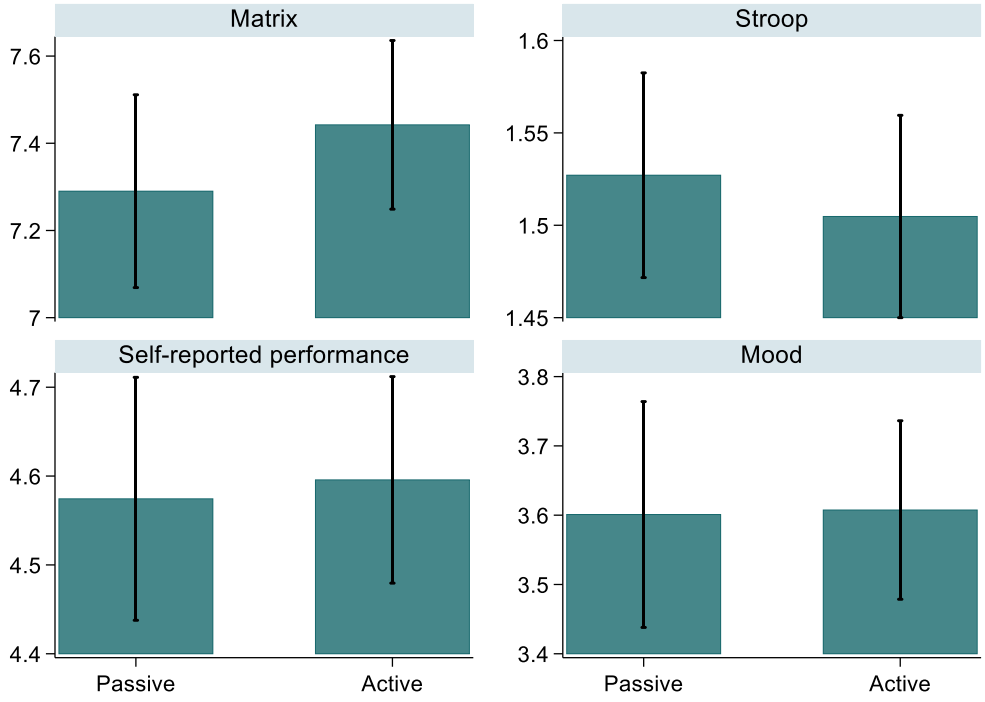


Figure 1 Mean score on outcomes, by reported travel mode.

Note: Vertical bars are 95 % confidence intervals, based on standard errors clustered at the student level to account for repeated observations from the same participant. N, observations=1083, N, students=456.

3.2 Induced mode change

Figure 2 shows travel mode shares across the four survey rounds. Walking and cycling declined during rounds with passive travel instructions (S2 and S3), before increasing again in S4, when active travel was encouraged. This pattern suggests that students responded to the instructions, although the changes were relatively modest.

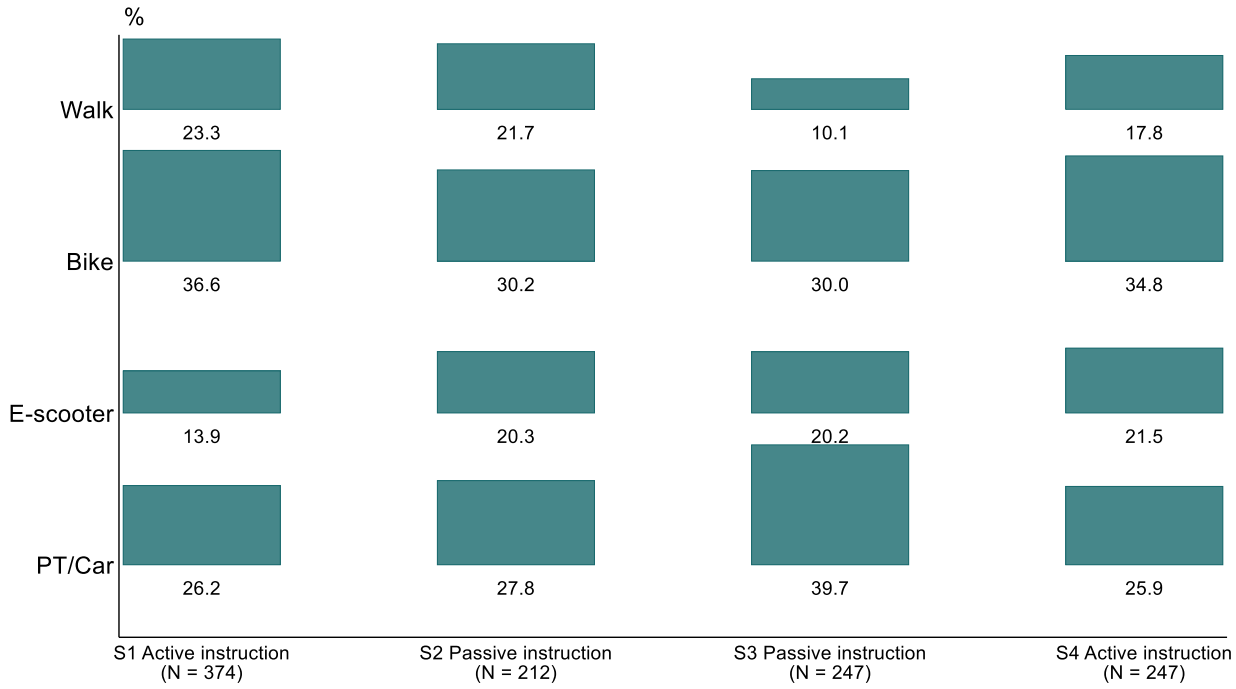


Figure 2 Percentage share of students who use the different modes in each survey round

Figure 3 shows transitions between active and passive travel modes across survey rounds, including only students observed in both rounds of each comparison. In line with the instructions, 32 students switched from active to passive travel between S1 and S2, and 37 switched from passive to active travel between S3 and S4. Switching occurred among both habitual active and passive travellers.

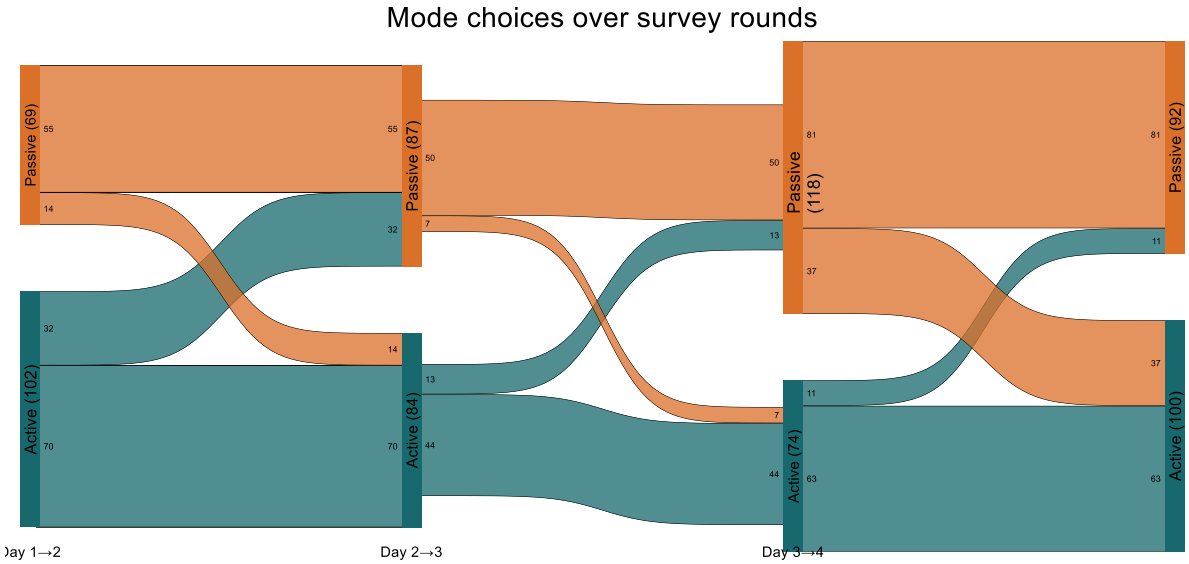


Figure 3 Sankey plot of transitions between active and passive modes over the four survey rounds. Transitions into missing excluded. (Number of observations for each transition in parenthesis. N, individuals: 322. N, observations: 949)

3.3 Within-individual comparisons

We compare outcomes within students who followed the travel mode instructions (compliers), pairing each active instruction day with each passive instruction day. Sample sizes vary across comparisons due to differences in participation and compliance.

Figure 4 illustrates the comparison between S1 and S2 (N=32), with outcomes standardised for comparability. Contrary to expectations, mood, self-reported performance and matrix scores were lower on the active travel day, while Stroop reaction times were longer. Only the difference in mood was statistically significant (p=0.016).

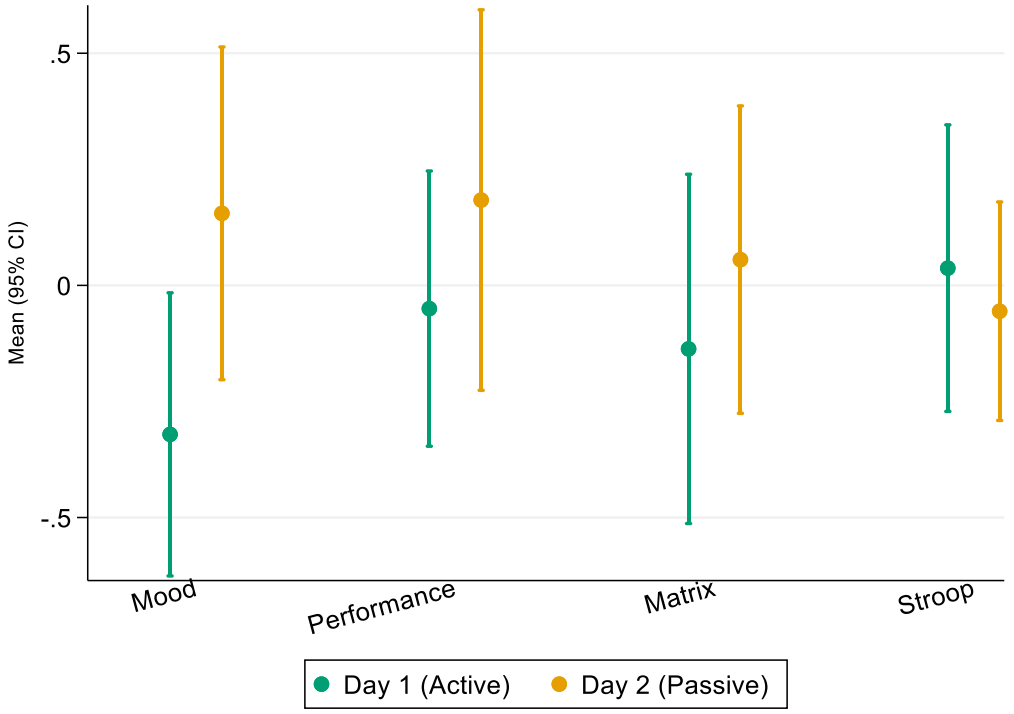


Figure 4 Mean mood and self-reported performance on day 1 and day 2 for individuals who followed mode instructions

Note: Sample: Respondents who switched mode according to instructions. N=32

Table 3 expands this simple comparison to all the possible pairwise comparisons across the active and passive instruction days and to all the outcome variables using pairwise t-tests. The table shows that all other differences are generally statistically insignificant. The exception is that compliers spend longer time on the Stroop task in survey round 1 relative to survey round 3 (passive instruction), suggesting slower executive function on the active travel day.

Table 3 Paired t-tests for compliers: mood, productivity, working memory, and executive function

Outcome	Comparison	Mean active	Mean passive	Difference	SE	p-value	N
Mood	R1 vs R2 (Week 1)	3.172	3.805	−0.633	0.249	0.016	32
	R4 vs R3 (Week 2)	3.431	3.667	−0.236	0.166	0.164	36
	R1 vs R3 (Cross-week)	3.704	3.462	0.242	0.161	0.138	60
	R4 vs R2 (Cross-week)	3.768	3.464	0.304	0.239	0.226	14
Self-reported performance	R1 vs R2 (Week 1)	4.521	4.792	−0.271	0.219	0.225	32
	R4 vs R3 (Week 2)	4.435	4.370	0.065	0.151	0.670	36
	R1 vs R3 (Cross-week)	4.428	4.428	0.000	0.160	1.000	60
	R4 vs R2 (Cross-week)	4.667	4.452	0.214	0.302	0.490	14
Working memory	R1 vs R2 (Week 1)	7.031	7.406	−0.375	0.290	0.206	32
	R4 vs R3 (Week 2)	7.667	7.861	−0.194	0.270	0.476	36
	R1 vs R3 (Cross-week)	7.700	7.550	0.150	0.203	0.463	60
	R4 vs R2 (Cross-week)	7.643	7.429	0.214	0.214	0.336	14

Executive function	R1 vs R2 (Week 1)	1.546	1.503	0.043	0.070	0.542	32
	R4 vs R3 (Week 2)	1.530	1.521	0.009	0.072	0.901	36
	R1 vs R3 (Cross-week)	1.624	1.469	0.159	0.045	0.001	60
	R4 vs R2 (Cross-week)	1.468	1.483	−0.015	0.115	0.897	14

Note: Difference = active-passive. SE = standard error of the mean difference. p-value from two-sided paired t-test. Sample conditioned on compliance (instructed_mode = chosen_mode) in both rounds. N = number of compliant individuals observed in both rounds.

3.4 Difference-in-difference

These within-person comparisons may still be affected by day-of-week variation or repeated exposure to the same questions and tests. To account for such time-varying influences, we compare compliers with non-compliers using the difference-in-differences approach described above.

Figure 5 illustrates this approach using minutes of active transport. Compliers spent on average 13 minutes more on active transport on the active instruction day than on the passive instruction day in week 1, and 15 minutes more in week 2. In contrast, the corresponding difference among non-compliers was less than one minute in either week, consistent with using the same travel mode on both days. The non-compliers thus provide a comparison group that helps account for time-varying confounders affecting both groups similarly.

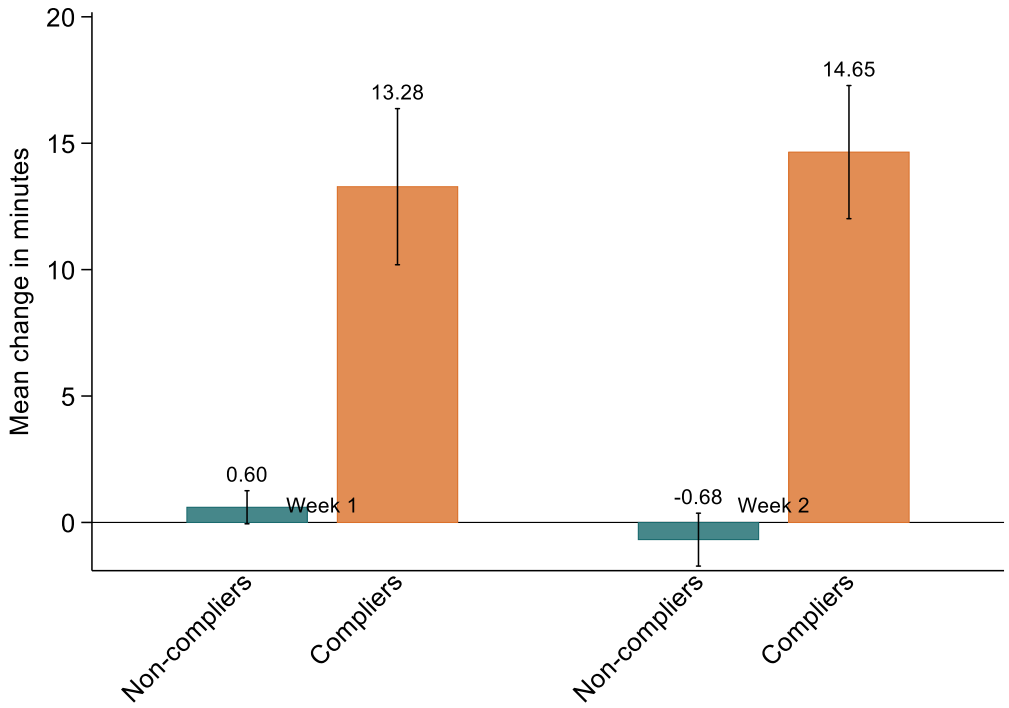


Figure 5. Difference in minutes of active travel between active and passive instruction days, by compliance status and week.

Note: Positive values indicate more active travel on active instruction days. Compliers switched modes as instructed; non-compliers maintained their travel mode. Error bars indicate 95% confidence intervals.

Figure 6 presents the difference-in-differences estimates for all four outcomes across the four pairwise comparisons (full statistics in Appendix Table A3). Mood estimates were significantly negative in both within-week comparisons (S1 vs S2 and S4 vs S3), suggesting relatively lower mood on active travel days among compliers compared with non-

compliers. However, this pattern was not consistent across comparisons, as the cross-week estimates were positive and non-significant. No significant differences were found for the other outcomes.

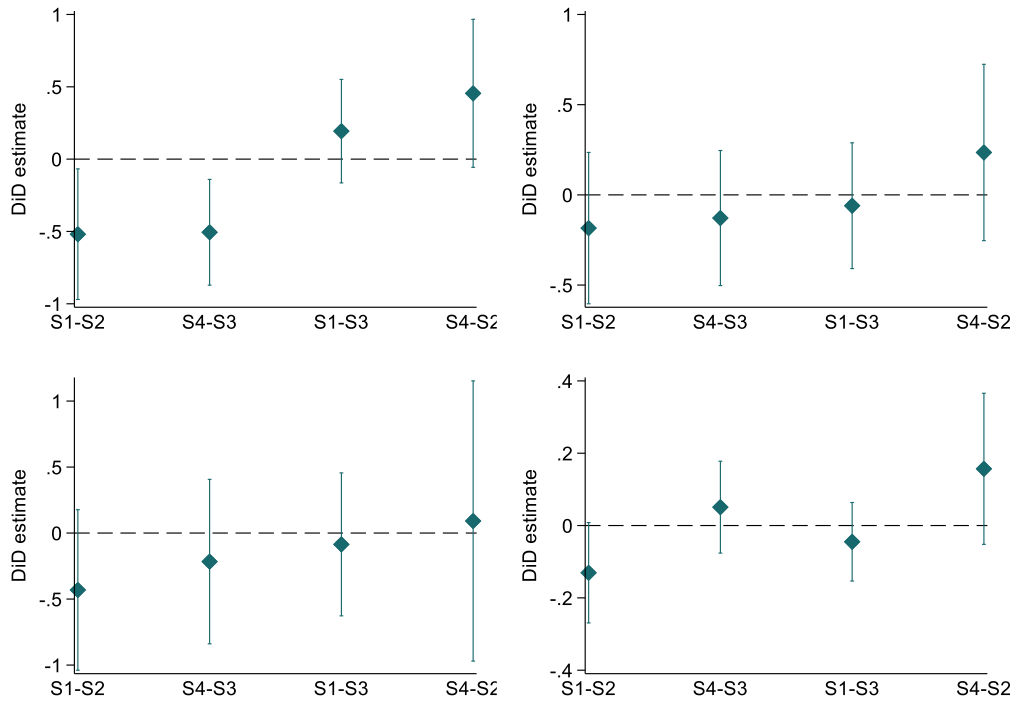


Figure 5 Difference-in-difference estimates: Difference in within-person change between active and passive day for compliers and non-compliers.

Note: Positive values indicate higher mood on a day with active instruction. Individuals switching opposite to instruction excluded. *Error bars represent 95% confidence intervals*.

4 Discussion

The present study examines whether adolescents experience differences in mood, self-reported performance, and cognitive performance on days when they travel actively to school compared with days when they travel using passive modes. Across a range of analytical approaches, we found little evidence that active school travel was associated with improved outcomes on the same day. Neither mood, self-reported performance, nor performance on two cognitive tests differed systematically between active and passive travel days. Some analyses even suggested a tendency towards slightly lower mood on active travel days, although these differences were generally small and did not reach statistical significance.

At first glance, these findings appear inconsistent with a substantial literature linking physical activity to improved mood and cognitive functioning (Buecker et al., 2021; Lubans et al., 2016). However, the implications of the present findings warrant careful consideration. Much of the existing evidence is based either on laboratory studies examining structured exercise under controlled conditions (Chang et al., 2012) or on observational comparisons between individuals in studies of active school travel (Stark et al., 2018, 2019; Ding & Feng, 2022). By contrast, the present study was designed specifically to capture short-term variation in psychological states in a real-world setting. By comparing repeated measurements within students shortly after school arrival, we address key limitations of previous research and provide a relatively direct test of the short-term effects of active school travel on mood and cognitive functioning, although small effects cannot be ruled out.

One possible explanation for the lack of positive effects is that the psychological benefits of active school travel may depend on whether the journey is experienced as enjoyable and autonomously chosen. Previous studies have associated active school travel with greater travel satisfaction and well-being (Friman et al., 2018; Stark et al., 2019; van den Berg et al., 2020; Wex et al., 2023) while research on physical activity suggests that autonomy-supportive contexts foster more autonomous motivation (Teixeira et al., 2012; Ntoumanis et al., 2021). Similarly, autonomous motivation for active travel among adolescents has been linked to satisfaction of the need for autonomy (Renninger et al., 2023). In our study, students were encouraged by their schools to use particular travel modes on specified days. Although the instructions were not compulsory, some students may have perceived them as controlling, potentially reducing enjoyment and offsetting any benefits of physical

activity. As we did not measure perceived autonomy or motivation, this interpretation remains speculative.

The school journey may also serve functions beyond transportation. For adolescents, travelling to school is often a social activity that provides opportunities to interact with friends and classmates (Fyhri et al., 2011). Changes in travel mode may therefore influence not only how students move but also whom they travel with and how they experience the journey. For some participants, complying with the active travel instruction may have influenced opportunities for social interaction during the trip. To the extent that social interaction during the journey contributes more to adolescent well-being than physical activity, any benefits of active travel may have been offset by reduced opportunities for socialising, leaving overall mood and functioning largely unchanged.

More fundamentally, the findings raise the possibility that the short-term psychological benefits often attributed to active travel may be less pronounced among adolescents than among adults. Existing evidence linking active transport to mood and performance comes predominantly from studies of adult commuters or from exercise interventions (Bourke et al., 2021, 2023; Chang et al., 2012; Fyhri et al., 2023; Ishihara et al., 2021; Ludyga et al., 2016; Yang et al., 2021). Both contexts differ substantially from adolescent school travel. Adults generally exercise greater autonomy over where they live, where they work, and how they travel, and the commute itself may serve different psychological functions. Furthermore, the presumed benefits of active commuting are often discussed in relation to work performance, productivity, and stress reduction. It remains unclear whether equivalent mechanisms operate in the same way among adolescents attending school.

The developmental context of adolescence may be particularly important in this regard. Adolescence is characterised by substantial biological, psychological, and social change. Hormonal changes, sleep disturbances, academic pressures, peer relationships, and identity development all contribute to considerable day-to-day variation in mood and functioning (Meeus, 2016; Toenders et al., 2024). Compared with these influences, the effects of a short walk or bicycle ride to school may be too small to detect amid adolescents' substantial day-to-day variation in mood and cognitive functioning, even if active travel contributes to health and well-being over longer periods.

From a policy perspective, these findings suggest caution in promoting active school travel primarily through claims of immediate improvements in mood, concentration, or academic performance. Active travel remains important as a source of daily physical activity and for its potential long-term health benefits. However, the present results provide little evidence

that adolescents experience measurable same-day psychological or cognitive benefits. If such benefits exist, they may depend more on the quality of the travel experience—including autonomy, enjoyment, and social interaction—than on physical activity alone.

4.1 Strengths and limitations

The present study has several strengths. First, unlike much of the existing literature, it employs a repeated-measures design that allows comparisons within the same individual across different travel days. This reduces the risk that observed associations are driven by stable differences between active and passive travellers. Second, outcomes were measured shortly after the journey took place, thereby reducing recall bias and increasing sensitivity to short-term fluctuations in psychological states. Third, the study combined self-reported measures with objective assessments of cognitive performance. Finally, the intervention successfully generated some variation in travel behaviour under real-world conditions, providing a stronger test of short-term effects than is typically possible in observational studies.

Several limitations should also be acknowledged. Most importantly, although the intervention succeeded in generating meaningful variation in travel behaviour, the number of participants contributing to the within-person analyses remained relatively modest (N=32), limiting statistical power. A central question is therefore whether expected effects are genuinely absent or merely too small to detect. Since the acute effects of physical activity are generally expected to be small, positive effects of active travel may nonetheless emerge in larger samples or over longer observation periods.

At the same time, attributing the null findings solely to insufficient statistical power would be overly simplistic. The estimated effects were generally close to zero and did not consistently point in the hypothesised direction. This suggests that any positive effects, if present at all, are unlikely to be large in magnitude. The findings therefore raise broader questions about whether assumptions derived from exercise research and studies of adult commuters necessarily apply to adolescents travelling to school.

The unbalanced panel structure further reduced the number of observations available for some analyses. In addition, we did not measure potentially important explanatory factors such as travel satisfaction, social interaction during the journey, perceived autonomy, or attitudes towards the instructed travel mode. Nor did we collect detailed information about physical exertion. Consequently, the study cannot determine whether the absence of

effects reflects a true lack of association or effects that are too small, heterogeneous, or context-dependent to be detected with the available data.

4.2 Future research

Future research should examine how adolescents experience their journeys, including enjoyment, social interaction and perceived autonomy, rather than focusing solely on travel mode. Larger repeated-measures studies are also needed to assess whether short-term effects vary by habitual travel mode, journey length or age, and to detect effects too small for the present study.

5 Conclusion

Using a repeated-measures field design, we found little evidence that active school travel improves adolescents' mood, self-reported performance or cognitive functioning shortly after arrival at school. While small effects cannot be ruled out, our findings suggest that immediate psychological benefits may be less universal than often assumed, and potentially depend on the experience and context of the journey.

6 Declarations

6.1 Ethics approval and consent to participate

The study was conducted in accordance with the Guidelines for Research Ethics in the Social Sciences and the Humanities issued by the Norwegian National Research Ethics Committees (NESH). Formal ethics committee approval was not required under the Norwegian framework for non-medical social science research. As the study collected only anonymous data, notification to Sikt (the Norwegian Agency for Shared Services in

Education and Research) was not required. Pupils and their parents or guardians were informed about the study and participation was voluntary. Passive parental-consent (opt-out consent) was used, whereby parents or legal guardians were informed about the study and given the opportunity to decline their child's participation. No written active consent was obtained. This procedure was in line with the recommendations and ethical guidelines of NESH.

6.2 Consent for publication

Not applicable. The manuscript does not contain identifiable individual participant information.

6.3 Availability of data and materials

The datasets generated and analysed during the current study will be deposited in a publicly accessible research data repository upon publication, subject to applicable data protection requirements. A persistent link to the dataset will be provided once available.

6.4 Competing interests

The authors declare that they have no competing interests.

6.5 Funding

This research was funded by The Research Council of Norway. The funder had no role in the study design, data collection, analysis, interpretation of data, or preparation of the manuscript.

6.6 Authors' contributions

AF and SES conceived and designed the study, conducted the data collection, performed the statistical analyses, and wrote the original manuscript. ACI, CP and ETB provided critical input throughout the research process and contributed to reviewing and revising the manuscript. All authors read and approved the final manuscript.

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Appendix

Table A1 **OLS regression on each of the outcomes with and without control variables**

	(1) Matrix	(2) Matrix	(3) Stroop	(4) Stroop	(5) Performance	(6) Performance	(7) Mood	(8) Mood
Active day	0.152	0.217	-0.022	-0.008	0.021	-0.068	0.006	-0.038
	(0.137)	(0.140)	(0.037)	(0.039)	(0.084)	(0.090)	(0.099)	(0.105)
Constant	7.290***	7.579***	1.527***	1.673***	4.574***	4.995***	3.601***	4.087***
	(0.112)	(0.196)	(0.028)	(0.075)	(0.070)	(0.144)	(0.083)	(0.150)
Control variables	No	Yes	No	Yes	No	Yes	No	Yes
Observations	1080	956	1049	947	1072	952	1078	956
Participants	456	377	439	377	454	376	455	377

Table A2 **Paired t-tests for compliers: mood, productivity, working memory, and executive function**

Outcome	Comparison	Mean active	Mean passive	Difference	SE	p-value	N

Mood	R1 vs R2 (Week 1)	3.172	3.805	−0.633	0.249	0.016	32
	R4 vs R3 (Week 2)	3.431	3.667	−0.236	0.166	0.164	36
	R1 vs R3 (Cross-week)	3.704	3.462	0.242	0.161	0.138	60
	R4 vs R2 (Cross-week)	3.768	3.464	0.304	0.239	0.226	14
Self-reported performance (self-reported)	R1 vs R2 (Week 1)	4.521	4.792	−0.271	0.219	0.225	32
	R4 vs R3 (Week 2)	4.435	4.370	0.065	0.151	0.670	36
	R1 vs R3 (Cross-week)	4.428	4.428	0.000	0.160	1.000	60
	R4 vs R2 (Cross-week)	4.667	4.452	0.214	0.302	0.490	14
Working memory	R1 vs R2 (Week 1)	7.031	7.406	−0.375	0.290	0.206	32
	R4 vs R3 (Week 2)	7.667	7.861	−0.194	0.270	0.476	36
	R1 vs R3 (Cross-week)	7.700	7.550	0.150	0.203	0.463	60
	R4 vs R2 (Cross-week)	7.643	7.429	0.214	0.214	0.336	14
Executive function	R1 vs R2 (Week 1)	1.546	1.503	0.043	0.070	0.542	32
	R4 vs R3 (Week 2)	1.530	1.521	0.009	0.072	0.901	36
	R1 vs R3 (Cross-week)	1.624	1.469	0.159	0.045	0.001	60

	R4 vs R2 (Cross-week)	1.468	1.483	−0.015	0.115	0.897	14

Note: Difference = active-passive. SE = standard error of the mean difference. p-value from two-sided paired t-test. Sample conditioned on compliance (instructed_mode = chosen_mode) in both rounds. N = number of compliant individuals observed in both rounds.

Table A3 Difference-in-difference: mood, productivity, working memory, and executive function

Outcome	Comparison	Difference complier	Difference non-complier	Difference-in-difference	T-stat	p-value	N compliers	N stayers
Mood	R1 vs R2 (Week 1)	-0.633	-0.114	-0.519	2.25	0.026	32	125
	R4 vs R3 (Week 2)	-0.243	0.262	-0.505	2.71	0.007	37	143
	R1 vs R3 (Cross-week)	0.242	0.048	0.193	-1.06	0.290	60	140
	R4 vs R2 (Cross-week)	0.304	-0.151	0.455	-1.74	0.084	14	114
Self-reported performance (self-reported)	R1 vs R2 (Week 1)	-0.271	-0.087	-0.184	0.86	0.391	32	123
	R4 vs R3 (Week 2)	0.072	0.200	-0.128	0.67	0.502	37	143
	R1 vs R3 (Cross-week)	-0.000	0.060	-0.060	0.34	0.736	60	139
	R4 vs R2 (Cross-week)	0.214	-0.021	0.235	-0.94	0.348	14	112

Working memory	R1 vs R2 (Week 1)	-0.375	0.056	-0.431	1.39	0.167	32	125
	R4 vs R3 (Week 2)	-0.216	0.000	-0.216	0.68	0.497	37	144
	R1 vs R3 (Cross-week)	0.150	0.236	-0.086	0.31	0.757	60	140
	R4 vs R2 (Cross-week)	0.214	0.123	0.091	-0.17	0.866	14	114
Executive function	R1 vs R2 (Week 1)	0.043	0.173	-0.131	1.84	0.067	32	123
	R4 vs R3 (Week 2)	0.003	-0.048	0.051	-0.79	0.433	37	139
	R1 vs R3 (Cross-week)	0.159	0.204	-0.045	0.81	0.419	59	136
	R4 vs R2 (Cross-week)	-0.015	-0.172	0.157	-1.47	0.143	14	109

Note: Difference in difference = $(within\ person\ change\ compliers) - (within\ person\ change\ non-compliers)$*. Withing person change is given by active instruction day less passive instruction day in all comparisons. Compliers follow instructions on both comparison days, while non-compliers travel by the same mode on both observation days. T-statistic and p-value from two-sided paired t-test.*