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Understanding Adolescents' Motivation for Active Travel from a Self-Determination Theory's perspective in the Decision-Making Process on Travel Mode Choice

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Abstract

Active travel (e.g., walking or cycling to reach a destination) provides a healthy, environmentally friendly, and accessible mode of transportation. Unfortunately, active travel among adolescents has decreased in Germany as well as in many other countries in recent years. Therefore, increasing research has been performed to better understand the mechanisms underlying travel mode choices. However, the majority of studies focus on younger children rather than adolescents and include active school travel while ignoring further destinations of adolescents' daily lives. Additionally, although interventions in other areas of physical activity emphasize the benefits of addressing motivation, specifically from the Self-Determination Theory (SDT) perspective, research on motivation toward active travel has only recently gained attention. This thesis aimed to enhance the knowledge of the association of motivation from the perspective of SDT with active travel behavior during decision-making on travel mode choice. Accordingly, this thesis includes validating a German instrument to assess behavioral regulation in general active travel (i.e., active travel to various destinations) in adolescent boys and girls. Further, it provides implications for sex/gender-sensitive intervention development based on identified differences regarding the strength and direction of the relationships between individual behavioral regulations with active travel in boys and girls. Addressing the notion that behaviors are likely to be motivated based on multiple reasons, this dissertation further examines clusters identifying six distinct profiles, which helped to explain active travel behavior to and from school, to friends/relatives, to shopping opportunities, and to leisure facilities. While not explicitly focusing on motivation, the qualitative study provides a conceptualization of the decision-making process on travel mode choice that helps to explore the complexities of motivation in decision-making. Overall, this thesis provides implications for future research aiming to develop interventions to promote active travel through motivational constructs based on SDT.

Keywords: active travel; motivation; basic psychological needs; self-determination theory; health promotion; decision-making process

Zusammenfassung

Aktive Mobilität (z. B. eine Destination zu Fuß oder mit dem Fahrrad erreichen) stellt eine gesunde, umweltfreundliche und zugängliche Art der Fortbewegung dar. Leider ist die Prävalenz der aktiven Mobilität unter Jugendlichen in Deutschland wie auch in vielen anderen Ländern in den letzten Jahren zurückgegangen. Aus diesem Grund wurde zunehmend Forschung betrieben, um die Mechanismen der Verkehrsmittelwahl besser zu verstehen. Die meisten Studien konzentrieren sich jedoch eher auf jüngere Kinder als auf Jugendliche und beziehen sich auf den aktiven Schulweg, während andere Ziele des täglichen Lebens von Jugendlichen außer Acht gelassen werden. Während Interventionen in anderen Bereichen der körperlichen Aktivität die Vorteile der Motivationsförderung, insbesondere aus der Perspektive der Selbstbestimmungstheorie (SBT), betonen, hat die Forschung zu Motivation im Kontext der aktiven Mobilität erst kürzlich an Bedeutung gewonnen. Ziel dieser Dissertation war es daher, das Wissen über den Zusammenhang zwischen Motivation aus der Perspektive der SBT und aktivem Mobilitätsverhalten während der Entscheidungsfindung zur Verkehrsmittelwahl zu erweitern. Daher beinhaltet diese Arbeit die Validierung eines deutschen Instruments zur Erfassung der Verhaltensregulationen von Jungen und Mädchen im Bereich der generellen aktiven Mobilität (d.h. des aktiven Reisens zu verschiedenen Zielen). Es werden Implikationen für die Entwicklung geschlechtsspezifischer Interventionen aufgezeigt, die auf den festgestellten Unterschieden hinsichtlich der Beziehungen zwischen Verhaltensregulationen und aktiver Mobilität bei Jungen und Mädchen beruhen. Aufgrund der Annahme, dass Verhaltensweisen aus mehreren Gründen motiviert sind, wurden in dieser Dissertation Profile identifiziert, die zur Erklärung des aktiven Mobilitätsverhaltens auf dem Weg zur und von der Schule, zu Freunden oder Verwandten, zu Einkaufsmöglichkeiten und zu Freizeiteinrichtungen beitragen. Die qualitative Studie fokussiert zwar nicht explizit Motivation, liefert aber eine Konzeptualisierung des Entscheidungsprozesses zur Wahl des Verkehrsmittels, die dazu beiträgt, die Komplexität der Motivation bei der Entscheidungsfindung zu verstehen. Insgesamt liefert die Dissertation Implikationen für zukünftige Interventionen zur Förderung der aktiven Mobilität durch motivationale Konstrukte basierend auf der SBT.

Schlüsselwörter: aktive Mobilität; Motivation; psychologische Grundbedürfnisse; Selbstbestimmungstheorie; Gesundheitsförderung; Entscheidungsfindung

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List of Abbreviations

ARRIVE   *Active travel behavior in the family environment*

AT   Active travel

BMI   Body mass index

BR-ACS   Behavioural Regulation in Active Commuting to and from School

CFA   Confirmatory factor analysis

HBSC   Health Behavior in School-aged Children

KiGGS   Gesundheit von Kindern und Jugendlichen in Deutschland (Engl. Study on health of children and adolescents in Germany)

SDG   Sustainable Development Goal

SDT   Self-Determination Theory

TPB   Theory of Planned Behavior

UN   United Nations

WHO   World Health Organization

1 Background

"More active people for a healthier world" – this vision was framed by the World Health Organization (WHO) in the Global Action Plan on Physical Activity (WHO, 2018b). This aim to increase physical activity among adults and adolescents is based on the many benefits of physical activity.

Physical activity helps maintain and promote health as well as prevent various non-communicable diseases. In children and adolescents, regular physical activity provides benefits for several physical, psychological, social, and cognitive health outcomes (Janssen & LeBlanc, 2010; Poitras et al., 2016). Among others, this includes the prevention of overweight and obesity, the development of muscle and bone health, as well as improved markers of metabolic and cardiovascular health (Alves & Alves, 2019; Janssen & LeBlanc, 2010; Poitras et al., 2016). Physical activity positively affects attention, executive functions, and academic performance (de Greeff, Bosker, Oosterlaan, Visscher, & Hartman, 2018). Furthermore, it contributes to improving mental health by reducing psychological ill-being (i.e., depression, stress, body image dissatisfaction) while increasing psychological well-being (i.e., self-image, satisfaction with life and happiness, body satisfaction) (Biddle & Asare, 2011; Gualdi-Russo, Rinaldo, & Zaccagni, 2022; Rodriguez-Ayllon et al., 2019) and health-related quality of life (Marker, Steele, & Noser, 2018; Wu et al., 2017). In addition, research suggests that an active and healthy lifestyle established in childhood and adolescence may persist into adulthood (Telama et al., 2014).

Despite these benefits, the prevalence of sufficient physical activity among adolescents is concerning. Globally, in a sample of 1.6 million adolescents aged 11-17, more than 80% (77.6% of boys, 84.7% of girls) engage less than one hour per day in moderate to vigorous intensity physical activity (Guthold, Stevens, Riley, & Bull, 2020). In Europe, about two-thirds of adolescents aged 10-18 are not sufficiently physically active (Steene-Johannessen et al., 2020). Specifically in Germany, the Health Behavior in School-aged Children (HBSC) study reports that only 10% of girls and 16.9% of boys aged 11, 13, and 15 years meet the WHO physical activity recommendations of a daily minimum of 60 minutes of moderate to vigorous physical activity (Bucksch et al., 2020). The Studie zur Gesundheit von Kindern und Jugendlichen in Deutschland (KiGGS, engl. Study on health of children and adolescents in Germany) found that in 11 – 13-year-olds only 16.5% of girls and 21.4% of boys, and in 14 – 17-year-olds only 7.5% of girls and 16% of boys meet the WHO's recommendations (Finger, Varnaccia, Borrmann, Lange, & Mensink, 2018).

To address this issue, the WHO summarizes different domains where adolescents can engage in physical activity, including recreation, physical education, transportation, and household chores (WHO, 2020). The transportation domain of physical activity refers to walking, cycling, and wheeling for the purpose of reaching a destination (WHO, 2020). Correspondingly, research findings support that active travel as a means of transportation can help to accumulate physical activity throughout the day. A synthesis of evidence found that in adolescents aged 12-17 years, active travel can contribute to 35-58% of daily moderate to vigorous physical activity (Prince, Butler, Rao, & Thompson, 2019). A global cross-sectional study in over 270,000 adolescents reports a 2.06 (95% CI: 2.01–2.12) increase in the odds of meeting the former WHO recommendations (at least 60 minutes of moderate- to vigorous-intensity physical activity daily) if adolescents traveled to school actively more than three times a week (Khan, Mandic, & Uddin, 2021). Additionally, active school travel can not only contribute directly to increased levels of physical activity through the journey itself but also through promoting a positive attitude towards physical activity, leading to more opportunities for physical activity being sought (Lam, Jayasinghe, Ahuja, & Hills, 2023). Further, interventions aiming to promote active travel behavior have the potential to successfully increase overall physical activity since adolescents might not compensate for the physical activity derived from active school travel on weekends or after school (Kek, García Bengoechea, Spence, & Mandic, 2019). This is supported by a review of walking interventions, which emphasizes the potential to promote physical activity among children and adolescents (Carlin, Murphy, & Gallagher, 2016), as well as by a review of 68 studies on the impact of active school travel on daily physical activity (Larouche, Saunders, Faulkner, Colley, & Tremblay, 2014).

1.1   Active travel in the context of the Sustainable Development Goals

In the 2030 Agenda for Sustainable Development, the United Nations (UN) established 17 interconnected global Sustainable Development Goals (SDGs) to ensure peace, prosperity, and health while protecting the planet (UN, 2016). The goals target a range of social, environmental, and economic issues, several of which can be addressed through people's transportation (UN, 2015). Although the potential of active travel is not yet explicitly addressed in the targets of the SDGs, it is a cross-cutting topic that can help achieve various SDGs.

Active travel can support achieving SDG 3, which concerns ensuring *good health and well-being* for all. First, research found associations of active travel with several markers of physical fitness (Henriques-Neto et al., 2020), including healthier body composition and improved cardiorespiratory health (Chillón et al., 2010; Lubans, Boreham, Kelly, & Foster, 2011; Martin-Moraleda, Mandic, Queralt, Romero-Blanco, & Aznar, 2022). Further, significant associations

were found with improved mental well-being (Larouche et al., 2014; Stark, Singleton, & Uhlmann, 2019) and reduced prevalence of psychological health complaints (Kleszczewska et al., 2020). Second, as outlined previously, active travel can contribute to increased physical activity among adolescents, thereby fostering improved health and well-being. Considering that physical activity can help explain socio-economic health differences in adolescents in Germany (Reuter et al., 2024), active travel can contribute to SDG 10 (*reduced inequalities*), providing an accessible and affordable travel mode for all individuals regardless of their socio-economic status. Research already supports that active travel tends to be more prevalent in more deprived areas (Corral-Abós et al., 2021; Molina-García, Menescardi, Estevan, Martínez-Bello, & Queralt, 2019; Olsen, Mitchell, Mutrie, Foley, & Ogilvie, 2017). Concerning health benefits, research found that switching from motorized to active travel was associated with more favorable body composition and that these effects were more substantial in adolescents from more deprived groups (Anthony, Thomas, Anna, Yvonne, & Christopher, 2021). Addressing another aspect of inequalities, SDG 5 focuses on *gender equality* and the empowerment of women and girls. Current research points to persistently lower physical activity levels in girls compared to boys globally (Guthold et al., 2020) and in Germany (Bucksch et al., 2020; Finger et al., 2018). At the same time, evidence from Norway suggests a stronger association of active travel with the compliance of WHO's physical activity recommendations in girls than in boys (Dalene et al., 2018). Consequently, girls can specifically benefit from active travel in terms of reaching physical activity recommendations, thereby contributing to better health.

Traveling actively also aligns with SDG 13, which addresses *climate change* and calls for urgent action. The WHO considers climate change the most significant health threat of the 21st century (WHO, 2018a). It directly (e.g., temperature change, drought, flood) and indirectly (e.g., water and air quality, land use change, ecological change) impacts many aspects of health such as mental illness, (non-)communicable diseases, undernutrition, water-borne diseases or heath strokes (WHO, 2018a). By reducing motorized transportation, active travel can help reduce greenhouse gas emissions (Brand, Dons, et al., 2021; Brand, Götschi, et al., 2021) and thus help mitigate climate change. For instance, substituting about 42% of short travel car trips (less than 3 miles) with walking or cycling could potentially reduce carbon emissions by 5% (Neves & Brand, 2019). As some strategies to promote physical activity can negatively influence climate and environments, active travel is unique as it provides both the desired benefits for individual health as well as for planetary health (Abu-Omar, Chevance, Tcymbal, Gelius, & Messing, 2023). Reducing motorized transportation with the help of active travel is particularly relevant in urban areas, where the population is exposed to high traffic

density, resulting in health costs such as air pollution, noise, or distress (Gössling, Nicolosi, & Litman, 2021). This highlights the potential of active travel to contribute to SDG 11, aiming at *sustainable cities and communities*, which includes reducing the environmental impact of cities, such as air pollution. Further, developing appropriate infrastructure to ensure safe and accessible travel, as specified by SDG 11, can effectively promote increased active travel since safety concerns are a major barrier to children's and adolescents' active travel (Aranda-Balboa, Huertas-Delgado, Herrador-Colmenero, Cardon, & Chillón, 2020; Wangzom, White, & Paay, 2023). This highlights the relationship between the role of active travel in advancing SDG 11 and the opportunities to increase active travel by directing efforts toward fulfilling SDG 11.

1.2 The need to understand and promote active travel behavior in adolescence

Given the many benefits of active travel, its promotion might be particularly successful when targeting adolescents.

First, health behaviors such as a physically active lifestyle are largely established at this age (Mikkelsen et al., 2019). The Young Finns Study supports this regarding physical activity and active travel: physical activity in three- to six-year-old children significantly predicted physical activity in youth and early adulthood (Telama et al., 2014). Regular active travel in adolescents was associated with higher physical activity in young adulthood after a follow-up period of 27 years (Yang et al., 2014). Additionally, a meta-analysis on physical activity during the adolescence-adulthood transition emphasizes the need for behavior change interventions during adolescence based on the increasing autonomy in adolescence and the potential that physical activity behaviors established during that time will likely last into adulthood (Corder et al., 2019). Further, during this stage of life, school transitions demonstrate valuable opportunities to promote active travel (Klos, Burchartz, et al., 2023). Consequently, adolescence might be one of the most sensitive and, at the same time, formative periods in the development of travel preferences and habits (Fitch, Rhemtulla, & Handy, 2019).

Second, there is room for improvement regarding the prevalence of active travel among adolescents living in Germany. Recent representative data from the MoMo study demonstrated a decrease in active school travel in 11-17-year-old schoolchildren in Germany from 2003 to 2017 (Reimers et al., 2021). While boys' active travel to school remained relatively stable, the prevalence in girls significantly decreased (Reimers et al., 2021). Overall, 21.5% of girls and 25.2% of boys reported regularly cycling to school, while less reported walking (17.7% of girls and 20.2% of boys). Another study from Germany suggested that

44.4% of girls and 72.9% of boys regularly cycle to school (Schönbach, Brindley, Reimers, Marques, & Demetriou, 2020). In a study from urban areas in Germany, about half of the adolescents (50.7%) who participated in the survey reported active school travel (Wex et al., 2023). While the prevalence of active travel to school is lower in some European countries, such as Scotland (46%) and Wales (31%), other European countries, including the Czech Republic (57%), Norway (59.4%), Spain (60%), and Switzerland (70%) exhibit higher prevalence compared to Germany (Gálvez-Fernández et al., 2021; Grize, Bringolf-Isler, Martin, & Braun-Fahrländer, 2010; Haug et al., 2021).

Third, appropriate intervention development is only possible when understanding the perspective of the adolescents themselves and not that of their parents. Parents are the key decision-makers in childhood regarding travel mode choice (Forsberg, Rutberg, Mikaelsson, & Lindqvist, 2020; Mah et al., 2017). However, with increasing age, autonomy (Corder et al., 2019) as well as independence from parents gain importance (Hadiwijaya, Klimstra, Vermunt, Branje, & Meeus, 2017), also leading to an increase in independent mobility (Shaw et al., 2015). Given that adolescents' perspectives on barriers to active travel might differ from those of their parents (Aranda-Balboa, Chillón, Saucedo-Araujo, Molina-García, & Huertas-Delgado, 2021; K. Wilson, Clark, & Gilliland, 2018), understanding active travel behavior in adolescence is essential for appropriate intervention development.

1.3 Adolescents' motivation and active travel behavior

To develop successful interventions to promote active travel among adolescents, it is necessary to understand the factors influencing their decision to choose an active travel mode. From a socio-economic perspective, key factors of influence associated with active travel operate on five levels: policy, built environment, community, interpersonal, and individual (Larouche & Ghekiere, 2018). Several frameworks have been introduced to conceptualize the relationships between these factors and how they lead to a decision on travel mode (Götschi et al., 2017).

An individual factor that has been found critical in changing and maintaining health behaviors is motivation (Ng et al., 2012; Ntoumanis et al., 2021; Ryan & Deci, 2017). Existing evidence advocates the use of theories to systematically identify determinants of health behaviors and calls for the application of behavior change theories for more effective intervention development (Gillison, Rouse, Standage, Sebire, & Ryan, 2019; Michie et al., 2017; Prestwich et al., 2014). Nevertheless, research on promoting active travel among children and adolescents widely lacks a theoretical foundation (Lu et al., 2014; Pang, Kubacki, & Rundle-Thiele, 2017). One promising psychological theory for understanding behavior is the Self-

Determination Theory (SDT; Deci & Ryan, 2000; Ryan & Deci, 2000, 2017), which has been successfully applied in several health domains (Ntoumanis et al., 2021).

In SDT, motivation is distinguished according to the varying extent to which it is controlled versus autonomous (see Figure 1).

Figure 1. *Motivation Taxonomy adapted from Ryan & Deci, 2000, 2017.*
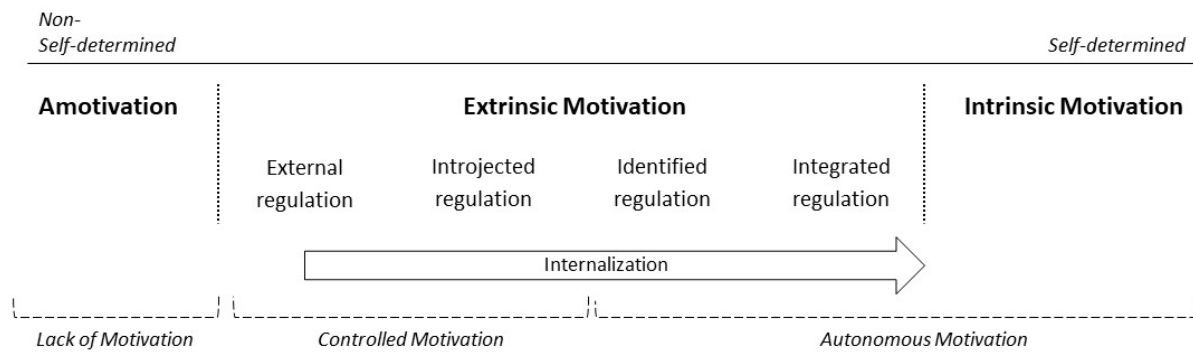
Intrinsic motivation represents the prototype of autonomous motivation and refers to self-determined behaviors that people perform only for the inherent enjoyment and satisfaction it brings. Extrinsic motivation, on the other hand, concerns behaviors performed for external reasons and to achieve outcomes separate from the behavior itself. From an SDT point of view, extrinsic motivation varies largely in the degree of autonomy, ranging from more controlled forms (external and introjected regulation) to more autonomous forms (identified and introjected regulation). The most controlled form of extrinsic motivation is external regulation, which concerns engaging in a behavior solely to receive external rewards or to avoid external punishment. Introjected regulation is more internalized than external regulation, referring to behaviors driven to fulfill internal demands such as the desire to maintain one's self-esteem or avoid guilt or shame. Both external and introjected regulation are described as controlled (non-self-determined) forms of motivation. The remaining two forms of extrinsic motivation, identified and integrated regulation, share many qualities with intrinsic motivation and thus can be combined to form autonomous (i.e., self-determined) motivation (Ryan & Deci, 2000). However, they differ from intrinsic motivation in that the motivation is not entirely internalized and pursues goals that are independent of the behavior itself. Identified regulation reflects behaviors where a person consciously values the importance or benefits of that behavior. Integrated regulation represents the most autonomous and internalized form of extrinsic motivation, in which a person perceives a behavior to align with their values and personality (Ryan & Deci, 2000, 2017). Although ordered along a continuum reflecting the relative autonomy of the various forms of motivation, SDT recognizes that intentional

behaviors are often manifoldly motivated (Ryan & Deci, 2022). In SDT, the absence of both intrinsic and extrinsic motivation is referred to as amotivation, which represents the lack of any motivation or intention to perform a behavior.

Overall, SDT suggests that autonomous forms of motivation (intrinsic motivation, identified regulation, integrated regulation) are particularly beneficial for the engagement, effort, and maintenance of the respective behavior, whereas controlled forms of motivation (external regulation and introjected regulation) and amotivation yield rather maladaptive outcomes (Deci & Ryan, 2000; Ryan & Deci, 2000, 2017). Previous research on physical activity supports the positive association of more autonomous forms of motivation with more or higher levels of physical activity (Owen, Smith, Lubans, Ng, & Lonsdale, 2014). In the domain of active travel, however, an SDT approach has only recently gained recognition. White, Parker, et al. (2018) developed a questionnaire to assess adolescents' motivation for active school travel from an SDT perspective. Still, they only considered the higher-level order constructs of autonomous motivation, controlled motivation and amotivation. In 2019, research from Spain adapted the Spanish Behavioural Regulation in Exercise Questionnaire-3 (BREQ-3; González-Cutre, Sicilia, & Fernández, 2010) to the context of active school travel and thus provided the first validated tool to assess the six behavioral regulations of motivation in this context among adolescents (Burgueño et al., 2019). This research was followed by translating and validating the questionnaire in Portugal (Marques et al., 2022) and Sweden (Burgueño et al., 2022). In the sample of adolescents from Spain, all three types of autonomous motivations were positively associated with active school travel, while neither the two types of controlled motivations nor amotivation was significantly associated (Burgueño et al., 2019). The positive associations of intrinsic motivation, integrated regulation, and identified regulation with active school travel were also found in the study from Sweden, which further identified a negative association of amotivation with active school travel (Burgueño et al., 2022).

Consequently, the internalization of motivation, which describes a person's natural tendency to transform controlled motivations into more autonomous motivations (Deci & Ryan, 2000; Ryan & Deci, 2000), is of central importance. To foster and sustain the internalization of regulatory processes and intrinsic motivation, satisfying three basic psychological needs, autonomy, competence, and relatedness, is essential (Deci & Ryan, 2000; Ryan & Deci, 2000, 2017). Autonomy concerns the feeling of being the origin of one's behavior; competence refers to the experienced sense of confidence or mastery while expressing one's capabilities; and relatedness includes the feeling of belonging and being a valuable member of a group (Ryan & Deci, 2017, 2020). The first research on adolescents' basic psychological need satisfaction regarding active travel was published in 2020, which provided the first validated

questionnaire for the context of adolescents' active school travel (Burgueño, González-Cutre, Sevil-Serrano, Herrador-Colmenero, Segura-Díaz, Medina-Casaubón, & Chillon, 2020). Again, this scale was translated and validated in Portugal (Marques et al., 2021) and Sweden (Burgueño, Lindqvist, Nyberg, Chillon, & Rutberg, 2023). Autonomy, competence and relatedness satisfaction were all significantly and positively associated with active school travel in the study from Sweden (Burgueño et al., 2023) and Spain (Burgueño, González-Cutre, Sevil-Serrano, Herrador-Colmenero, Segura-Díaz, Medina-Casaubón, & Chillon, 2020), while research from Portugal did not investigate such associations (Marques et al., 2022).

1.4   Gaps of knowledge and aims of the thesis

This dissertation investigated adolescents' decision-making regarding travel mode choices, with particular emphasis on motivation for general active travel using an SDT perspective. By focusing on adolescents' travel behavior, this research aims to fill a gap in the existing literature, which mainly centers on younger children (Aranda-Balboa et al., 2020; Carlin et al., 2016; Schönbach, Altenburg, Marques, Chinapaw, & Demetriou, 2020). Additionally, this thesis addresses the knowledge gap concerning active travel beyond the school domain. Although research suggests that only 36% of trips are made by 10 to 19-year-olds to reach school, while 40% are made related to leisure time activities (Nobis & Kuhnimhof, 2018), existing studies on active travel in youth predominantly concentrate on commuting to and from school (Carlin et al., 2016; Schoeppe, Duncan, Badland, Oliver, & Curtis, 2013). Consequently, focusing solely on active school travel might waste potential to promote physical activity among adolescents, as traveling to other leisure-related places holds the same positive associations with physical activity as active travel to school (Schoeppe et al., 2013).

Specifically, the research within this dissertation sought to examine the following facets of adolescents' travel mode choices:

a) Provide a German questionnaire to assess motivation for general active travel

To the best of our knowledge, no validated instrument is currently available for assessing the six behavioral regulations of motivation regarding active travel among adolescents in the German context. Questionnaires to assess behavioral regulation in active school travel were validated in research from Spain (Burgueño et al., 2019), Portugal (Marques et al., 2022), and Sweden (Burgueño et al., 2022). Nevertheless, the existing research is destination-specific, concerning motivation for active travel to and from school. Thus, this dissertation provides the first German questionnaire to assess boys' and girls' behavioral regulations in general active travel without focusing solely on the school setting (Renninger et al., 2022).

b) Explore motivation from an SDT perspective as a determinant of active travel behavior

This dissertation includes a variable- and a person-centered approach to gain a comprehensive understanding of motivation as a determinant of adolescents' active travel behavior.

The variable-centered approach addresses the lack of studies which adequately consider sex/gender[1] in the promotion of active travel in children or adolescents (Marzi et al., 2020), despite the recognized importance of applying a sex/gender-sensitive approach to health behaviors (Schlund et al., 2021). This lack of sex/gender-sensitive studies is concerning, given the significant difference in the prevalence of active travel between boys and girls globally (Costa, Adamakis, O'Brien, & Martins, 2020; Haug et al., 2021; Kek et al., 2019; Leslie, Kremer, Toumbourou, & Williams, 2010). Although findings from Germany are conflicting regarding significant differences between boys and girls (Reimers et al., 2021; Schönbach, Brindley, et al., 2020), a sex/gender gap regarding physical activity in Germany cannot be denied (Bucksch et al., 2020; Finger et al., 2018). Consequently, a sex/gender-specific understanding of the determinants of active travel that allows tailored interventions could help narrow the sex/gender gap in physical activity. Nevertheless, none of the existing research on SDT in active travel included an examination of differences between boys and girls in terms of motivation for active travel (Burgueño et al., 2019; Burgueño et al., 2022; Marques et al., 2022). The sex/gender-sensitive investigation of the relationship of behavioral regulations with active travel behavior in adolescent boys and girls (Renninger et al., 2022) aims to contribute to a more in-depth understanding of the determinants of active travel.

The person-centered approach aimed to identify clusters among adolescents that share motivational characteristics. As this research specifically recognizes that behaviors are likely to be motivated by several reasons simultaneously (Howard et al., 2020; Ryan & Deci, 2022), all six behavior regulations of motivation (intrinsic motivation, integrated regulation, identified regulation, introjected regulation, external regulation, and amotivation) were included. Besides this, this person-centered approach aimed to improve understanding of the composition of clusters by including satisfaction of the three basic psychological needs (autonomy satisfaction, competence satisfaction, and relatedness satisfaction). Further, this research aimed to investigate the relevance of profiles that are based on motivation for general active travel for destination-specific active travel behavior that included travel to and

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[1] Following the recommendations from the Cochrane Sex/Gender Methods Group , we use the term sex/gender to acknowledge interconnection between socially induced gender-related factors and sex-based biological/physiological attributes, impacting health behaviors.

from school, to friends/relatives, to shopping opportunities, and to leisure facilities (Renninger, Bachner, et al., 2023). To the best of our knowledge, there are no comparable studies yet that approach motivation for active travel from a person-centered perspective.

c) Conceptualize the decision-making process on travel mode choice from adolescents' perspective

While extensive research has identified various quantitative determinants of active travel, understanding and conceptualizing the relationships of all determinants with each other and how they produce a decision for a travel mode is challenging (Götschi et al., 2017). Based on a review that discussed and summarized existing conceptual frameworks of travel behavior, Götschi et al. (2017) illustrated such relationships between determinants of active travel. Alongside, they identified another key feature in the frameworks, which concerns a generic choice process. This decision-making process represents the central pathway of choosing a travel mode while considering all relevant factors influencing travel behavior (e.g., motivation). Existing frameworks addressing travel mode choices among adolescents or children lack any conceptualization or incorporation of such a decision-making process (Mandic et al., 2015; McMillan, 2005; Mitra, 2013; Panter, Jones, & van Sluijs, 2008; Pont, Ziviani, Wadley, & Abbott, 2011). Recognizing that all factors influencing travel mode choices are processed during decision-making underscores the importance of conceptualizing the decision-making process from adolescents' perspective. Thus, the research included in this dissertation concerns the understanding of adolescents' experiences of the decision-making process on travel mode choice (Renninger, Reimers, et al., 2023). Filling this gap is essential for understanding how motivation is integrated into the decision-making process and subsequently impacts travel mode choices.

2 Methods

2.1 The ARRIVE study

The three studies included in this thesis were conducted as part of the cross-sectional ARRIVE study (Active tRavel BehaviouR in the FamIly EnVironmEnt), which aimed to evaluate and understand the travel mode choices of adolescents living in Germany (Reimers et al., 2022). In particular, the focus was to produce the first evidence dealing with adolescents' travel behavior to several destinations of daily living. Thus, we utilized the term 'general active travel' in the ARRIVE study, as opposed to the term 'active school travel'.

We initially reviewed existing theoretical frameworks on youths' travel behavior to develop a theoretical framework for the ARRIVE study. Based on the conceptual framework proposed by Panter et al. (2008), we conducted a second literature search on potential determinants of active travel among adolescents. Subsequently, we incorporated the identified determinants into an adapted version of the conceptual framework from Panter et al. (2008). The study's protocol presents the framework in detail (Reimers et al., 2022). Figure 2 provides an overview version of the framework, highlighting the contribution of the research embedded in this thesis within the ARRIVE study.

Figure 2. *Conceptual Framework for the ARRIVE study, adapted from the study protocol (Reimers et al., 2022).*
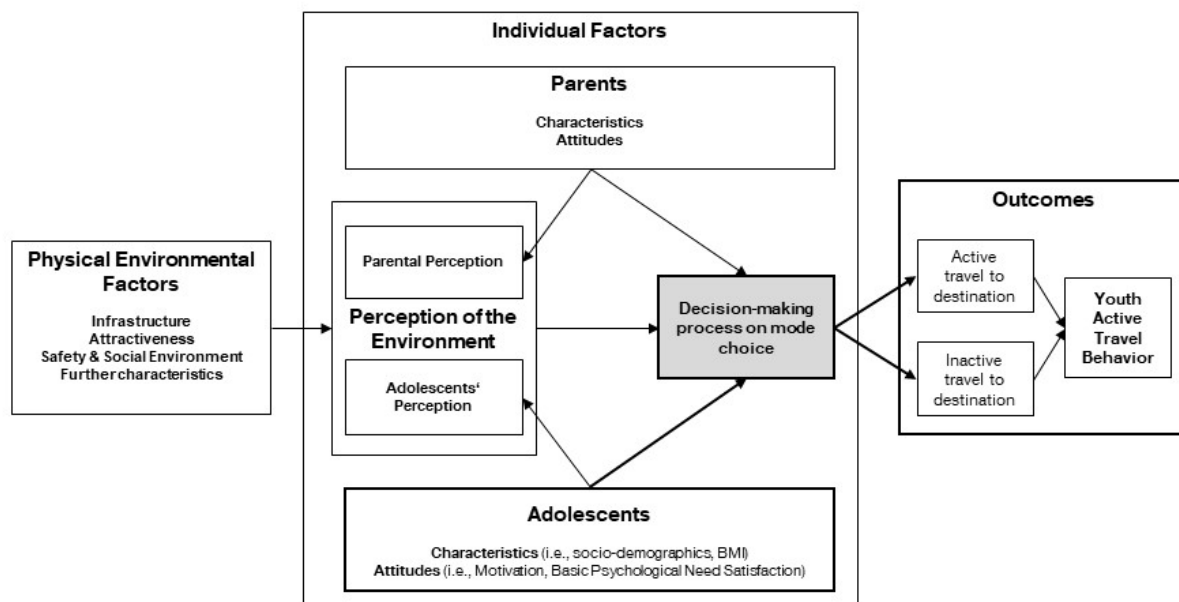
Note: bold black lines outline the contribution of the studies included in this dissertation.

ARRIVE included a quantitative and a qualitative study. The quantitative research specifically focused on the empirical evaluation of theoretical relationships of active travel and its

determinants. For the qualitative study, semi-structured interviews with adolescents and their parents were conducted to gain a deeper understanding of the decision-making on travel mode choice from their perspectives. For both studies, we aimed to include families with adolescents aged between 11 to 15 years. This was based on evidence from Germany, which identified adolescents aged 11 to 17 at particularly high risk for passive school travel (Reimers et al., 2021). Additionally, a sharp decrease in active travel to school was found in students from Finland in the age range of 12-15 years (Yang et al., 2014). Lastly, international data suggests a decrease in physical activity in this age group, which eventually stabilizes at the age of 15 years (Steene-Johannessen et al., 2020).

2.2 Quantitative research (Publication 1 and 2)

The quantitative survey of the ARRIVE study consisted of two parts. Parents were asked to complete the first section of the survey. Among other things, this section included questions on their personal and their child's characteristics (e.g., sociodemographic data, BMI), their own travel behavior, and diverse perceived barriers or facilitators towards their child's active travel. After the parents finished this section, the adolescents answered the second section independently. This section involved questions on the adolescent's travel and physical activity behavior, perceptions of support and environment, as well as questions on basic psychological needs and motivation for active travel. A summary of all instruments used to assess the individual constructs is provided in the study protocol (Reimers et al., 2022). Data was collected in June 2021 using an existing nationwide online panel, which is representative of the population in Germany in terms of age, sex/gender, education, and place of residence. All adolescents were recruited via parents. Therefore, 1747 parents with at least one offspring between 11-15 years were invited to participate in the survey. Within the ARRIVE study, we aimed to recruit a nationwide balanced sample of approximately equal numbers of participating fathers and mothers with roughly equal numbers of sons and daughters. This resulted in 518 parents with 518 adolescents who completed the survey.

2.2.1 Questionnaire to assess adolescents' behavioral regulation in general active travel

To assess adolescents' motivation for general active travel, we adapted the Spanish Behavioral Regulation in Active Commuting to and from School (BR-ACS) Questionnaire, which was found to be a valid and reliable tool in adolescents (Burgueño et al., 2019). To address the issue of the focus on active school travel in the original Spanish BR-ACS, "to and from school" was replaced with "cover a distance" (dt. "lege Wege zurück"). During the translation to the German context, which was conducted by two researchers independently, we also considered the wording used in the German translation (Rausch Osthoff, 2017) of the

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revised Behavioral Regulation in Exercise Questionnaire (P. M. Wilson, Rodgers, Loitz, & Scime, 2006). We reviewed this first version of the questionnaire with three German experts on children's and adolescents' physical activity and SDT-based motivation concerning semantic, idiomatic, conceptual, and cultural appropriateness. Next, an independent researcher back translated the German and reviewed items to check for consistency with the content of the original items. Lastly, we asked four adolescents (two girls, two boys) to provide feedback on the reviewed questionnaire, which resulted in the final German version.

After data collection, we validated the German version of the questionnaire. Therefore, we conducted a confirmatory factor analysis (CFA) to test the six-factor structure (intrinsic motivation, integrated regulation, identified regulation, introjected regulation, external regulation, and amotivation) by the simplex structure of behavioral regulations according to SDT (Markland & Tobin, 2004; P. M. Wilson et al., 2006). We refrained from validating a hierarchical three-factor model including the higher-order factors autonomous motivation (including intrinsic motivation, integrated regulation, and identified regulation as primary-order factors), controlled motivation (including introjected and external regulation as primary-order factors), and amotivation, although comparable research in the field included this analysis (Burgueño et al., 2019; Burgueño et al., 2022; Marques et al., 2022). This was based on the consideration that higher-order models are neither theoretically nor empirically supported and that scores summarizing autonomous and controlled motivation reduce information and explanatory value (Howard et al., 2020). Thus, we support using individual scores for the six behavioral regulations. Fit measures used to inform about model fit included chi-squared test (χ^2-test), chi-square and degrees of freedom ratio (χ^2/df), comparative fit index (CFI), Tucker-Lewis index (TLI), root mean square error of approximation (RMSEA), and standardized root mean square residual (SRMR). To ensure the applicability of the instrument in boys and girls, we performed a multi-group factor analysis of invariance across sex/gender. Thus, we tested for configural invariance (same structure across sex/gender groups), metric invariance (same factor loadings across sex/gender groups), scalar invariance (same item intercepts across sex/gender groups), and error variance invariance (same error variance across sex/gender groups) according to Milfont and Fischer (2010).

2.2.2 Behavioral regulations in general active travel using sex/gender-sensitive analyses

In the first step, we assessed differences between boys (n = 263) and girls (n = 254) regarding active travel behavior and the six behavioral regulations (intrinsic motivation, integrated regulation, identified regulation, introjected regulation, external regulation, and amotivation). One adolescent indicated a diverse gender and was excluded from the analysis as the sample

size was too small to allow separate analyses. We used Levene's test (with a significance level of p < 0.05) to assess equality of variances across the sex/gender groups. As Levene's test indicated homoscedasticity regarding identified regulation, introjected regulation, external regulation, and amotivation, a two-sided t-test (with a significance level of p < 0.05) was used to test for sex/gender differences. Regarding intrinsic motivation and integrated regulation, homoscedasticity could not be assumed; thus, Welch's t-test was used (with a significance level of p < 0.05).

Second, we assessed the association of adolescents' active travel behavior with the six behavioral regulations using logistic regression analyses. Thus, intrinsic motivation, integrated regulation, identified regulation, introjected regulation, external regulation, and amotivation served as the predictor variables, and active travel behavior as the dependent variable. Based on a socio-ecological perspective, we included possible confounding variables from the individual (age), social (social support), and environmental (degree of urbanization) levels. To enable sex/gender-sensitive interpretation of the results, including identifying potentially most beneficial or detrimental behavioral regulation specific for boys and girls, we performed regression analyses for the whole sample and separately for boys and girls. The level of significance for Wald test was set to p < 0.05. Finally, we calculated odds ratios with a 95% Confidence Interval from regression coefficients.

2.2.3 Cluster analysis to identify profiles including motivation and basic psychological needs satisfaction in general active travel

A person-centered approach was used to identify groups among adolescents who share homogeneous characteristics regarding intrinsic motivation, integrated regulation, identified regulation, introjected regulation, external regulation, amotivation, autonomy satisfaction, competence satisfaction, and relatedness satisfaction regarding active travel. For this purpose, self-organizing maps (SOM) analysis was conducted as this approach holds several advantages. First, SOM visualizes the results plotted on two-dimensional maps, which facilitates understanding of cluster composition as well as the relationships across input variables and thus advances interpretation (Wehrens, 2009). Next, compared to other clustering methods, SOM can produce more accurate results (Budayan, Dikmen, & Birgonul, 2009; Melo Riveros, Cardenas Espitia, & Aparicio Pico, 2019). Further, statistical power does not decrease with an increase in input variables (Herrero-Herrero, García-Massó, Martínez-Corralo, Prades-Piñón, & Sanchis-Alfonso, 2017). Lastly, SOM employs an unsupervised algorithm, specifically useful for non-linear models (Herrero-Herrero et al., 2017). This corresponds to the exploratory approach of this study, which was based on the findings from the first study that highlighted the specificity of the non-voluntary nature of traveling to a

destination (Renninger et al., 2022), as well as on the assumption that behaviors might be multiple motivated (Howard et al., 2020). The SOM analysis included three phases: 1) building a neuron network, 2) assigning an initial weight to each input variable, and 3) iteratively modifying the weights of neurons by training algorithms (Pellicer-Chenoll et al., 2015). After identifying the map with the minimum error (Pellicer-Chenoll et al., 2015), neurons were clustered into groups using k-means method. A six-cluster solution was chosen based on the Davies-Bouldin index (Davies & Bouldin, 1979).

After identifying the six clusters, further analyses examined:

- differences between the six clusters in the nine input variables (Welch's ANOVA including Games-Howell post-hoc procedure; level of significance $p < 0.05$)
- differences between the six clusters in adolescents' overall active travel (Welch's ANOVA including Games-Howell post-hoc procedure; level of significance $p < 0.05$)
- association of clusters with travel mode to and from school, friends or relatives, shopping facilities, and leisure facilities (Chi-squared test; level of significance $p < 0.05$)
- association of clusters with travel distance to friends or relatives, shopping facilities, and leisure facilities (Chi-squared test; level of significance $p < 0.05$)
- differences between the six clusters in distance to school (Welch's ANOVA including Games-Howell post-hoc procedure; level of significance $p < 0.05$)
- association of clusters with sex/gender (Chi-squared test; level of significance $p < 0.05$)
- differences between the six clusters in body mass index (BMI) and age (ANOVA, level of significance $p < 0.05$)

2.3   Qualitative research (Publication 3)

Within the qualitative part of the ARRIVE study, we conducted semi-structured interviews with 13 adolescents, 12 mothers, and seven fathers. Interviews took place online from September to November 2021. We interviewed adolescents and parents individually, one after the other, when possible. Parents were not present during the interviews with the adolescent. For the publication included in this dissertation, interviews with adolescents were used. The development of the initial interview guide is explained in Renninger, Reimers, et al. (2023). The interview guide was structured to depict two destinations an adolescent had recently reached. Both destinations were discussed with adolescents concerning their experiences using both an active travel mode and a passive travel mode. The English version of this initial interview guide can be found in the protocol of the ARRIVE study (Reimers et al., 2022). During the data

collection process, the conducted interviews were analyzed continuously with regard to the research question. Thus, after the first seven interviews, we refined the interview guide to obtain more information on decision-making regarding any travel mode and not solely differentiating between active and passive travel. Further, this modified interview guide aimed at a more open conversation with the participants. An English version of the interview guide can be found in the supplementary material of Renninger, Reimers, et al. (2023).

We recorded the audio during the interviews, which was later transcribed verbatim. To analyze the data, Thematic Analysis (Braun & Clarke, 2006; Braun, Clarke, & Weate, 2016) was used. The analysis process was reflexive and iterative, including the six steps of Thematic Analysis: 1) Familiarizing yourself with the data, 2) Generating initial codes, 3) Searching for themes, 4) Reviewing potential themes, 5) Defining and naming themes, 6) Producing the report (Braun & Clarke, 2006). A deductive and inductive approach to the data was used during the analyses. On the one hand, adolescents' decision-making was inductively explored without any predefined codes. Nevertheless, the analysis was informed by the theoretical background of Panter et al. (2008), which assumes that all factors associated with adolescents' travel behavior are processed during decision-making. We conducted the research from a realist's perspective, considering that we could capture the actual experiences of adolescents through their stories (Clarke & Braun, 2013).

3 Publications

3.1 Publication 1: Motivation and active travel in adolescent girls and boys in Germany – Findings from the ARRIVE study

Summary:

Previous research lacks a comprehensive understanding of sex/gender differences in the motivational determinants of active travel behavior among adolescents. Thus, this study examined sex/gender differences in behavioral regulations towards general active travel in 263 boys and 254 girls living in Germany. Further, we addressed how the six behavioral regulations relate to active travel behavior in boys compared to girls. Results indicate a significant difference in active travel behavior, intrinsic motivation, and amotivation. Compared to girls, boys reported higher levels of active travel behavior and intrinsic motivation. Contrarily, girls demonstrated higher levels of amotivation. These results suggested that boys might benefit from their higher levels of intrinsic motivation regarding active travel behavior, while girls may be (qualitatively) less motivated to engage in active travel. However, results from the regression analyses could not confirm this. In contrast to SDT's assumptions, intrinsic motivation was not significantly associated with active travel behavior neither in boys nor in girls or when analyzing the whole sample. Identified regulation was beneficial for promoting active travel behavior in boys, while integrated and external regulation was more relevant for girls. Consistent with SDT, amotivation was negatively associated with active travel in both boys and girls. First, findings emphasize the importance of considering sex/gender differences in future analyses and intervention development to contribute to understanding and promoting active travel behavior. Specifically, analyzing the whole sample without differentiating between boys and girls would have masked these differences and, correspondingly, would have allowed less tailored interventions. Regarding intervention development, it might be particularly useful to promote identified regulation in boys, while girls might benefit most from promoting integrated and external regulation. Further, our findings emphasize the unique context of traveling, which implies that traveling

is hardly undertaken merely for the enjoyment of traveling, but for the purpose to reach a specific destination. This calls for further research within SDT in a context driven by external demands.

Additionally, this research includes the validation of the survey instrument used to measure behavioral regulation in general active travel. Although there are already validated questionnaires for the target group of adolescents that deal with behavioral regulations, these are validated for the languages Spanish, Portuguese, and Swedish and refer to active school travel (Burgueño et al., 2019; Burgueño et al., 2022; Marques et al., 2022). Thus, this research provides the first valid questionnaire in the population of German-speaking adolescent boys and girls regarding behavioral regulation in general active travel.

The manuscript was submitted to *Transportation Research Part F: Psychology and Behaviour* in March 2022 and accepted and published in September 2022. *Transportation Research Part F: Psychology and Behaviour* is a peer-reviewed international journal (Q1, Impact Factor: 4.1) that focuses on the psychological and behavioral aspects of traveling.

Contribution:

Denise Renninger was the leading author of this article and performed data analyses. Together with Yolanda Demetriou she developed the idea for this publication. Denise Renninger wrote the original draft of the article and made revisions based on the review and editing from all other authors.

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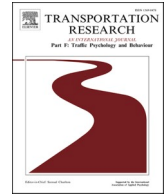
Motivation and active travel in adolescent girls and boys in Germany – Findings from the ARRIVE study

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ABSTRACT

Active travel (using an active mode of transport such as walking or cycling) contributes to the accumulation of daily physical activity and thus holds potential for promoting health. To promote active travel among adolescents an in-depth understanding of determinants from a sex/gender perspective is needed. Within Self-Determination Theory (SDT), it is proposed that the quality of an individuals' motivation (i.e., the degree to which it is autonomous) determines the extent to which they engage in particular behaviors and perform them effectively. As part of the ARRIVE study, the aim of this research was to investigate the relationship between motivation and active travel in adolescent boys (N = 263, M_{age} = 12.92) and girls (N = 254, M_{age} = 13.21) from a nationwide German sample. Results showed significant group differences between male and female adolescents in the proportion of trips traveled actively, intrinsic motivation and amotivation. Logistic regression analyses demonstrated different relationships of the different types of motivation proposed within SDT on active travel behavior depending on sex/gender. In the total sample, integrated and identified regulation increased the odds of active travel (by 15.8 %, and 20.3 % respectively), whereas amotivation decreased the odds by 23.0 %. Intrinsic motivation and controlled forms of extrinsic motivation (i.e. introjected and external regulation) did not significantly change the odds of active travel. Separate sex/gender-specific analyses were conducted. For boys, only identified regulation significantly increased the odds of active travel (by 40.2 %) and amotivation significantly decreased the odds (by 18.8 %). In girls, integrated (by 25.3 %) and external (by 20.3 %) regulation significantly increased the odds of active travel, while amotivation (26.6 %) significantly decreased the odds. We conclude that disparities exist in the relationship among different regulation types with active travel behavior between adolescent boys and girls, and that findings contradictory to SDT might result from the specific context of traveling to a destination. Considering the regression analyses findings, future interventions to promote active travel among adolescents should incorporate sex/gender-sensitive development, because some behavioral regulations might not be equally effective among girls and boys.

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1. Introduction

The majority of young people in Europe and around the globe fail to meet the recommended amount of physical activity (PA) (Guthold, Stevens, Riley, & Bull, 2020; Steene-Johannessen et al., 2020) of an average of at least 60 min/day across the week (Bull et al., 2020; WHO, 2020). This is concerning because the health benefits of PA in childhood and adolescence are evidenced (Janssen & LeBlanc, 2010; Poitras et al., 2016; WHO, 2020). Further, these PA-related health benefits as well as the PA behaviors can persist into adulthood (Corder et al., 2019; Telama et al., 2014). Recent research reinforces a PA gap between boys and girls, with girls being consistently less active across all age groups (Guthold et al., 2020; Steene-Johannessen et al., 2020). This is also evident in Germany with girls meeting the WHO guidelines less frequently than boys (Burchartz et al., 2021).

Past research has shown that active travel (AT) (e.g. walking or cycling to a destination) does not only contribute to adolescents' daily PA (Carlin, Murphy, & Gallagher, 2016; Larouche, Saunders, Faulkner, Colley, & Tremblay, 2014), but it can also enhance several markers of physical fitness, such as cardiorespiratory fitness, muscular strength or body composition (Henriques-Neto et al., 2020). Further, AT helped to reduce the prevalence of non-specific psychosomatic complaints (Kleszczewska et al., 2020).

However, recent research from several countries has demonstrated a declining or generally low prevalence of AT in adolescence (Haug et al., 2021; Larouche, 2018). Internationally, differences between boys and girls in the prevalence of AT or in travel mode have been identified, including Australia (Leslie, Kremer, Toumbourou, & Williams, 2010), Ireland (Costa, Adamakis, O'Brien, & Martins, 2020), Wales and Scotland (Haug et al., 2021), the Czech Republic (Pavelka et al., 2017), and New Zealand (Kek, García Bengoechea, Spence, & Mandic, 2019; Smith et al., 2019). In Germany, however, the MoMo Study did not find significant sex/gender[1] differences in AT to school. Nevertheless, the prevalence of walking (girls: 17.7 %; boys: 20.2 %) and cycling (girls: 21.5 %; boys: 25.2 %) to school was low among adolescents aged 11–17 years, which also indicated a tending difference in the choice of travel mode (Reimers et al., 2020). Additionally, a study in Southern Germany among 12 to 15 year-olds showed that girls were significantly less likely to cycle to school than boys (Schönbach, Brindley, Reimers, Marques, & Demetriou, 2020). Thus, there is still room for improvement for adolescent boys and girls. Apart from the benefit both boys and girls could gain from increased AT, promoting girls' AT might specifically contribute to reducing the sex/gender gap in PA, since girls generally demonstrate lower PA levels than boys (Guthold et al., 2020; Steene-Johannessen et al., 2020). The importance of taking a sex/gender-differentiated approach to health behaviors has been highlighted by recent research in the field of sex/gender (Schlund et al., 2021). Nevertheless, especially intervention studies concerning the promotion of AT in children and adolescents do not sufficiently consider sex/gender (Marzi et al., 2020). To facilitate the development of sex/gender-sensitive intervention programs, the determinants of adolescents' travel behavior should be examined from such a sex/gender perspective.

From a social-ecological standpoint, AT behavior is influenced by individual, interpersonal, community, built environment and policy determinants (Larouche & Ghekiere, 2018). On the individual level, motivation has the potential to positively influence health behaviors such as AT behavior (Ntoumanis et al., 2021; Ryan & Deci, 2017; Schönbach, Vondung, et al., 2020).

Among numerous psychological theories concerning motivation, Self-Determination Theory (SDT; Ryan & Deci, 2017) is an established framework to examine motivational processes for health-related behaviors and to design interventions (Ng et al., 2012). Research substantiates the applicability of SDT in PA settings (Teixeira, Carraça, Markland, Silva, & Ryan, 2012). More specifically aligned with the current work, SDT has been applied in the context of children's and adolescents' PA participation (Owen, Smith, Lubans, Ng, & Lonsdale, 2014; Vasconcellos et al., 2020) as well as more recently to the context of AT to and from school (Burgueño et al., 2019; Burgueño et al., 2020; Marques et al., 2022; Marques et al., 2021).

In addressing motivation (i.e., why people are moved to act), SDT focuses not only on quantity but also on the quality of motivation. According to SDT, two general types of motivation (i.e., controlled motivation and autonomous motivation) as well as the construct of amotivation exist and are ordered along a continuum according to the degree of their autonomy (Ryan & Deci, 2017). At the one end of the continuum, amotivation represents a state in which a person lacks any autonomy or intention to engage in a behavior. Ascending according to the degree of relative autonomy, amotivation is followed by the controlled forms of motivation, which are regulated by external factors such as receiving rewards or avoiding punishments (external regulation), or by internal desires for example to avoid a feeling of guilt or maintain self-esteem (introjected regulation). Moving along the continuum, the autonomous forms of motivation are the result of the conscious value a person ascribes to the behavior (identified regulation), the congruence with personal needs, values, and goals (integrated regulation), or the mere interest, enjoyment and satisfaction that a person obtains by performing the behavior (intrinsic motivation). In the literature, this dimensional structure results in different approaches to capture motivation (Howard et al., 2020; Kelso et al., 2020). Recent research emphasizes the value of differentiating the motivational types according to their behavioral regulation, as it can encourage meaningful intervention development, for example, by supporting decision-making on the conveying focus of activities (e.g. enjoyment, meaning, reward) (Howard et al., 2020). In terms of sex/gender differences in behavioral regulations, Teixeira et al. (2012) recommended that researchers acknowledge their potential existence and break down data across sex/gender accordingly. Their findings suggest a disparity between males and females in the strength and effect of each behavioral regulation on behavior. Specifically, they reported that certain behavioral regulations were more positively associated with exercise in females while showing no or negative associations in males and vice versa. Although their research focuses on an adult population and exercise, their findings and suggestions are still relevant to our investigation.

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[1] The term sex/gender aims to recognize the entanglement of the socially induced gender-related factors and the sex-based biological / physiological attributes that interact to influence health behaviours. To recognize this, we follow the recommendations of the Cochrane Sex/Gender Methods Group by using the term sex/gender (Sex/Gender Methods Group; Springer, Mager Stellman, & Jordan-Young, 2012).

Research conducted in Spain provided initial evidence to support the relevance of the motivation types within SDT and AT to school. Specifically, Burgueño et al. (2019) reported that the autonomous forms of motivation (i.e. intrinsic motivation, integrated regulation, and identified regulation) positively predicted adolescents' AT behavior to school. However, this study did not investigate potential sex/gender differences in the six behavioral regulations or whether each regulatory style had equal influences on AT behavior in adolescent girls and boys. Further, the research conducted by Burgueño et al. (2019) was limited to the school domain. Generally, previous studies on AT predominantly focused on AT to/from school (Carlin et al., 2016; Schoeppe, Duncan, Badland, Oliver, & Curtis, 2013) although research suggests that school is just one among several destinations that adolescents frequently travel to in everyday life (Nobis & Kuhnimhof, 2018). Moreover, most studies focus on younger children rather than adolescents (Aranda-Balboa, Huertas-Delgado, Herrador-Colmenero, Cardon, & Chillón, 2020; Carlin et al., 2016; Schönbach, Altenburg, Marques, Chinapaw, & Demetriou, 2020), even though adolescence represents a critical life stage where changes in health behaviors (e.g. AT behavior) are likely to occur and to be carried over into adulthood (Mikkelsen et al., 2019).

Therefore, the present study aims to specifically address these lacks of knowledge by i) taking a sex/gender oriented approach to the motivational determinant of AT behavior; ii) focusing on AT in general by addressing more destinations of daily life than school; and iii) including adolescents aged 11–15 years. To the best of our knowledge, no previous study has examined the motivational mechanisms in general AT in adolescent boys and girls from a sex/gender-sensitive perspective.

Based on the reported importance to identify determinants of general AT behavior coupled with the outlined lack of knowledge, the purposes of this work were twofold. First, this study aimed to systematically investigate whether sex/gender differences exist in the different behavioral regulations for AT. Second, the aim was to examine whether there are disparities in the effects of different regulation types on AT behavior between adolescent boys and girls. Overall, we hypothesize that the six behavioral regulations will help to explain AT behavior in adolescent boys and girls. By investigating the relationships of the behavioral regulations with AT behavior, this study contributes to the overarching aim of the ARRIVE study, to empirically evaluate the theoretical relationships of diverse determinates with general AT behavior in adolescents (Reimers et al., 2022).

2. Methods

2.1. Study design

The present investigation is part of the ARRIVE (Active tRavel behavioR in the famIly enVironmEnt) study, a cross-sectional study to explore social and individual factors within the family environment that influence adolescents' AT behavior (Reimers et al., 2022). For this purpose, the 'Conceptual Framework for the Environmental Determinants of Active Travel in Children' by Panter, Jones, and van Sluijs (2008) was used. The proposed categories of this framework were supplied with several evidence based determinants of adolescents' travel behavior.

2.2. Procedure of data collection

The data collection was conducted in June 2021 by the means of computer-assisted web interviewing. Adolescents were recruited via their parents, by the use of an existing German-wide online panel (forsa.omninet), which is representative of the German population with regard to age, gender, education, and place of residence. The sample was drawn purposively, in order to achieve an approximately equal number of mothers and fathers with approximately equal number of daughters and sons aged 11–15 years. A minimum sample size of 500 parents and 500 adolescents was targeted (Bujang, Sa'at, Sidik, & Joo, 2018). The survey questionnaires were provided online using an online tool specifically developed by Forsa. Parents were recruited offline via telephone interviewing to ensure the representation of people who rarely use the internet within the sample. After parents provided informed consent for participation in the survey, they received a link to the questionnaire via e-mail. The survey was divided into two parts: parents completed the first part of the survey and adolescents responded to the second part. First, parents were informed about the purpose of the study and asked to answer the questions truthfully. After parents had completed the respective part of the questionnaire, they were asked to provide the link to the adolescent so as to let the adolescents fill in the questionnaire on their own. Parents were advised to only be available for possible comprehension questions. Then, adolescents received the information on the study's purpose and how to answer questions. Adolescents also provided informed consent for participation before responding to the remaining questions. Before every new section of the questionnaire, adolescents were informed about the following content, reminded to answer the questions truthfully, and told that there were no right or wrong answers to the study items. To ensure full completion of the questionnaires, participants had to provide answers to every single item in order to move to the next page and to successfully complete the survey. In the case of more adolescents within the age of 11–15 years in the family, parents were instructed to choose the adolescent whose first name comes first in the alphabet. The current analyses are only based on the adolescent survey. In total, the adolescent survey took about 15 min to complete.

2.3. Study population

The study population consisted of 254 girls ($M_{age} = 12.92 \pm 1.35$) and 263 boys ($M_{age} = 13.21 \pm 1.33$) from cities with>100,000 inhabitants (29.2 %), medium-sized towns consisting of 20,000–99,999 inhabitants (17.4 %), small towns with 5,000–19,999 inhabitants (22.2 %), and regions with<5,000 inhabitants (30.8 %) across the whole of Germany. 87.2 % of adolescents reported no migration background, 10.3 % indicated a migration background from one parent and 2.5 % reported a migration background from

Table 1
Characteristics of the study population.

	Total	Boys	Girls
N	517	263 (51 %)	254 (49 %)
Age			
11	81	31	50
12	113	60	53
13	109	52	57
14	119	64	55
15	95	56	39
Residence			
cities (>100,000 inhabitants)	151	78	73
medium-sized towns (20,000–99,999 inhabitants)	90	45	45
small towns (5,000–19,999 inhabitants)	115	59	56
rural areas (<5,000 inhabitants)	159	80	79
Missing	2		
Type of school			
Primary School	12	4	8
Secondary School (Mittelschule*)	24	13	11
Secondary School (Realschule*)	99	55	44
Secondary School (Gymnasium*)	294	140	154
Comprehensive secondary School*	74	43	31
Other	10	5	5
Missing	4		
Migration background			
Yes, from both parents	13	9	4
Yes, from one parent	53	27	26
No migration background	451	227	224
Perceived social support for AT from parents[**]	5.50 (1.01)	5.54 (0.06)	5.48 (0.06)

Note:

[*] In Germany, students in secondary school are taught at different performance levels either in one school (comprehensive secondary school) or in separate schools (Hauptschule, Realschule or Gymnasium).

[**] measured on a 7-point Likert Scale and expressed as a mean value (standard deviation); for detailed information on measurement please see (Reimers et al., 2022).

both parents. Details on characteristics of the study population are presented in Table 1. One adolescent was excluded prior to analyses because the adolescent indicated a diverse gender and the sample size of n = 1 was too small to allow for a separate analysis.

2.4. Measures

2.4.1. Travel behavior

Adolescents indicated transport mode (e.g. by bike, by bus, by car, etc.) to several destinations, which have previously been identified as relevant in adolescent populations from Germany (Nobis & Kuhnimhof, 2018). Thus, the five ways assessed included the way to and from school, to friends/relatives, to shopping facilities and to destinations for leisure-time activities. For this purpose, the Mode and Frequency of Commuting To and From School Questionnaire (Segura-Diaz et al., 2020) was modified and translated to German. The responses on mode of transport were given based on a questionnaire from the Mobility in Germany survey (Mobilität in Deutschland, MiD) (Eggs et al., 2018). Responses to the mode of transport for each trip were later coded into either active (e.g. walking, cycling) or passive (e.g. being driven by car, using public transport). Subsequently, two sum scores for each participant were calculated, indicating the total number of ways traveled actively and passively (i.e. ranging from 0 to 5 ways traveled actively; 0 – 5 ways traveled passively). However, some adolescents indicated, that they did not travel to some of the destinations at all. Therefore, a second (additional) value was calculated for each adolescent: the proportion of ways traveled actively. For this purpose, we used the total number of ways that an adolescent reported to undertake actively and passively ($N_{ways\ traveled\ actively} + N_{ways\ traveled\ passively}$), resulting in a value ranging from 0 to 5) and the number of ways traveled actively ($N_{ways\ traveled\ actively}$). From this, we calculated the proportion of ways traveled actively for each participant:

$$Proportion\ of\ ways\ traveled\ actively = \frac{N_{ways\ traveled\ actively}}{N_{ways\ traveled\ actively} + N_{ways\ traveled\ passively}} \times 100$$

The same procedure was followed to calculate the proportion of ways traveled passively:

$$Proportion \ of \ ways \ traveled \ passively = \frac{N_{ways \ traveled \ passively}}{N_{ways \ traveled \ actively} + N_{ways \ traveled \ passively}} \times 100$$

2.4.2. Behavioral regulation in active travel

The Spanish Behavioural Regulation in Active Commuting to and from School (BR-ACS) Questionnaire (Burgueño et al., 2019) was translated to German and adapted to obtain information about behavioral regulation towards AT in general (with no exclusive focus on AT to/from school). For this purpose, two independent researchers translated the BR-ACS into German and adapted the focus from the original school setting (i.e. I walk or cycle to and from school because…) to general AT (i.e. I cover distances by foot or bike because…). After the resulting two versions of the questionnaire were discussed to reach a consensual first German version, three experts in the field of youth's activity behaviors and motivation reviewed the first German version in terms of semantic, idiomatic, conceptual, and cultural equivalences. The second version was then given to an independent translator to assess whether the German items reflected the content of the original items. The resulting version was tested for acceptability and understanding by two boys and two girls. Based on their feedback, the final German version of the BR-ACS questionnaire was established and used in the study. In total, 23 items on a 5-point Likert Scale assessed behavioral regulation in AT including intrinsic motivation (four items; e.g. I cover distances by foot or bike because it's fun), integrated (four items; e.g. I cover distances by foot or bike because it is consistent with my own values), identified (three items; e.g. I cover distances by foot or bike because I value the advantages), introjected (four items; e.g. I cover distances by foot or bike because I feel guilty when I don't do so) and external regulation (four items; e.g. I cover distances by foot or bike because other people say I should do so), and amotivation (four items; e.g. I don't see the sense of covering distances by foot or bike). For each subscale measuring the respective regulation, an average value was calculated. The adapted German questionnaire including an English translation is enclosed in the supplementary material (Supplementary 1).

2.5. Data analysis

Data analysis was performed in R (R Core Team, 2020) using the psych (Revelle, 2021) and car (Fox & Weisberg, 2019) packages. According to the recommendation from Flake, Pek, and Hehman (2017), the validity of the German version of the questionnaire for measuring behavioral regulation in AT was examined as it was translated and adapted from the original. The factor structure for the translated German version of the BR-ACS was assessed via AMOS (version 27.0; Armonk, NY, USA).

First, descriptive statistics for travel behavior and for each subscale of the questionnaire on behavioral regulation in AT was estimated for the whole sample, and separately for boys and girls.

Second, a confirmatory factor analysis (CFA) tested the six-factor structure of the questionnaire used for the present sample. Maximum likelihood method with Bollen-Stine bootstrap correction (5000 samples) was used since Mardia's test for normality indicated that the data might not be normally distributed (total sample: Mardia's coefficient = 128.756, critical ration (c.r.) = 43.165) (Kline, 2015). According to the recommendation to use a combination of diverse fit measures (Hu & Bentler, 1999), the following fit indices were considered to inform about model fit: chi-squared test (χ^2-test), chi-square and degrees of freedom ratio (χ^2/df), the comparative fit index (CFI), the Tucker-Lewis index (TLI), the root mean square error of approximation (RMSEA) and the standardized root mean square residual (SRMR). Because the sensitivity of the χ^2-test increases with sample size, even small deviations from a perfect model lead to the rejection of the model (Hu & Bentler, 1999). Thus, we additionally included the χ^2/df, which is appropriate with values below 3 (Kline, 2015). CFI and TLI indicate good model fit with values around 0.95. However, CFI and TLI values lower or equal to 0.08 still indicate good model fit, if SRMR (<0.11) and RMSEA (<0.08) are also taken into account (Hu & Bentler, 1999). Additionally, the 90 % confidence interval for the RMSEA should not include 0 and the upper border should not exceed 0.10 (Kline, 2015). The standardized regression weights values should be above 0.40 (Hair, Anderson, Babin, & Black, 2010) and correlations among latent variables should not exceed values>0.85 so as to demonstrate an adequate conceptual discrimination (Kline, 2015). Next, to test whether the item characteristics can be compared between girls and boys, a multi-group factor analysis of invariance across sex/gender was performed according to Milfont and Fischer (2010). Whether the more restrictive model fits, was evaluated by means of χ^2-difference test. Additionally, both models are considered to reflect the data structure equally well, as long as differences in CFI and RMSEA remain below values of 0.010 and 0.015 respectively (Chen, 2007). For reliability analysis, internal consistency of the subscales was calculated through Cronbach's alpha with the respective values indicating excellent > 0.9, good > 0.8, acceptable > 0.7, questionable > 0.6, poor > 0.5, and unacceptable < 0.5 fit (Blanz, 2021). Additionally, composite reliability was assessed indicating good internal consistency with values greater or equal to 0.70 (Hair et al., 2010). Average Variance Extracted (AVE) indicates good convergent validity with values equal to or>0.50 (Hair et al., 2010), yet, AVE values below 0.50 can still be accepted when composite reliability is>0.60 (Fornell & Larcker, 1981).

Results of the CFA showed an appropriate fit of the data to the proposed model, sex/gender differences in behavioral regulations towards AT were investigated in a third step. To test for equality of variances across the sex/gender groups, Levene's test was carried out for the variables of intrinsic motivation, integrated, identified, introjected and external regulation, amotivation and travel behavior. If the resulting p-value indicated significance (<0.05), homoscedasticity could not be assumed. Thus, to test sex/gender differences in those cases, the Welch's t-test was conducted. When the Levene's test did not reveal significant differences in variances, a two-sided t-test was used. Differences in travel behavior between adolescent girls and boys were analyzed using the proportion of ways traveled actively or passively, to account for the bias that some adolescents did not travel to all five destinations. A two-sided t-test was used with the level of significance set to p <.05.

Lastly, to assess the effect of the behavioral regulations on AT behavior, a logistic regression analysis was conducted including the

behavioral regulations as predictor variables and travel behavior as the dependent variable. For this purpose, the sum scores of ways traveled actively and passively were supplied in the glm function in R to denote success (ways traveled actively) and failure (ways traveled passively). This procedure takes the different amount of ways taken into account by calculating the probability of success (traveling to a destination using an active mode of transport). In order to get a better understanding of how the six behavioral regulations operate within both sex/genders, the regression analysis was performed for the whole sample and separately for girls and boys. Regression analyses were controlled for age, social support and degree of urbanization. Regression coefficients (b) were then transformed to odds ratios (OR) via the exponential function of the regression coefficient (e^b) (Szumilas, 2010). To determine statistical significance, the obtained p-value from the Wald test was considered for each regression parameter and set to < 0.05 with a 95 % confidence interval (95 %CI).

3. Results

3.1. Descriptive statistics of travel behavior

Across the whole sample, adolescents reported to usually cover 3.05 of the ways actively and 1.87 ways passively. On average, girls used an active mode of transport for 2.83 trips whereas boys traveled actively 3.26 trips. A passive mode of transport was used on average for 1.66 ways by boys and for 2.09 ways by girls. Four adolescents reported not to travel to friends/relatives, 18 adolescents reported not traveling to leisure time facilities, and 18 adolescents reported not undertaking trips to shopping facilities. Including this information, adolescents reported active travel to 62 % of ways on average and passive travel to 38 % of the ways on average. On average, girls reported to actively travel 58 % of the ways and 42 % passively. Boys reported to actively travel 66 % of the ways and 34 % passively on average.

3.2. Confirmatory factor analyses of the questionnaire used to assess behavioral regulation in active travel

The CFA indicated acceptable model fit: χ^2 (215, N = 517) = 739.59, p = .00; χ^2/df = 3.44; CFI = 0.92; TLI = 0.91; SRMR = 0.079; RMSEA[90 %CI] = 0.069 [0.063,0.074]; p-close = 0.000. Standardized regression weights ranged from 0.55 (item 7) to 0.89 (item 10). The simplex structure proposed within SDT was supported, whereby the latent variables (i.e. the six behavioral regulations) were more strongly and positively correlated to those that are theoretically adjacent than to more distant ones. Details on latent correlations (ranging from −53 to 0.93) and factor loadings are provided in the supplementary material (Supplementary 2). In addition, and as shown in Table 2, Cronbach's alpha values ranged from 0.69 (introjected regulation) to 0.91 (intrinsic motivation), indicating acceptable internal consistently for all subscales except for introjected regulation, where consistency was marginally below 0.70. However, composite reliability values all remained equal or above 0.70 demonstrating good internal consistency. Average variance extracted values ranged from 0.37 (introjected regulation) to 0.72 (intrinsic motivation).

3.3. Invariance analysis

Table 3 shows model fit indices for the three constrained models. Differences in CFI and RMSEA remained below 0.010 and 0.015, respectively, supporting factor invariance across sex/gender.

3.4. Sex/gender differences

Compared to girls (M = 0.58; SD = 0.32), boys (M = 0.66; SD = 0.30) reported a significantly higher proportion of ways which they usually travel actively, t(5 1 5) = 3.20; p = .001; d = 0.28. For the behavioral regulations, significant differences between boys and girls were found in intrinsic motivation and amotivation (see Table 4 for means, standard deviations, p-values and effect sizes). Compared to girls, boys expressed significant higher levels in intrinsic motivation and significant lower levels in amotivation. However, Hedges' g shows only small effects. No differences between boys and girls were found in integrated, identified, introjected or external regulation. Descriptive statistics of the proportion of active and passive ways, and of the behavioral regulations are presented in Table 4 for the overall sample and with regard to sex/gender.

Table 2
Cronbach's alpha, composite reliability and average variance extracted for the six subscales from the questionnaire on behavioral regulation towards active travel.

	Cronbach's alpha	CR	AVE
Intrinsic motivation	0.91	0.91	0.72
Integrated regulation	0.89	0.90	0.68
Identified regulation	0.72	0.73	0.48
Introjected regulation	0.69	0.70	0.37
External regulation	0.74	0.73	0.42
Amotivation	0.87	0.87	0.62

CR = composite reliability, AVE = average value extracted.

Table 3
Factor invariance across sex/gender.

	χ^2	df	χ^2/df	CFI	TLI	SRMR	RMSEA [90 %CI]	MC	$\Delta\chi^2$	ΔCFI	ΔRMSEA
Configural invariance	1020.983	430	2.374	0.911	0.895	0.0809	0.052 [0.048, 0.056]				
Metric invariance	1045.862	447	2.340	0.910	0.898	0.0842	0.051 [0.047, 0.055]	2 vs 1	24.879	−0.001	−0.001
Scalar invariance	1099.543	470	2.339	0.905	0.898	0.0840	0.051 [0.047, 0.055]	3 vs 2	40.155*	−0.005	0.000
Error variance invariance	1174.404	514	2.285	0.901	0.902	0.0891	0.050 [0.046, 0.054]	4 vs 3	74.861*	−0.004	−0.001

MC = Model Comparison, 1 = Configural invariance model, 2 = Metric invariance model, 3 = Scalar invariance model, 4 = Error variance invariance model.
  * significant Chi-square difference with p <.05.

Table 4
Description of the six subscales from the questionnaire on behavioral regulation towards active travel and ways traveled actively and passively, for total sample, boys and girls.

		Mean, SD	Skew	Kurtosis	p-value[a,b]
Intrinsic motivation	Total	3.51, 1.05	−0.51	−0.41	
	Boys	3.62, 0.97	−0.51	−0.22	.01[a*]
	Girls	3.39, 1.12	−0.44	−0.68	g = 0.22
Integrated regulation	Total	3.01, 1.12	−0.01	−0.87	
	Boys	3.08, 1.07	0	−0.74	.12[a]
	Girls	2.93, 1.16	0.02	−1	
Identified regulation	Total	3.12, 1.03	−0.18	−0.65	
	Boys	3.14, 1.00	−0.16	−0.57	.62[b]
	Girls	3.10, 1.06	−0.19	−0.75	
Introjected regulation	Total	1.78, 0.76	1.02	0.72	
	Boys	1.80, 0.74	0.96	0.82	.63[b]
	Girls	1.77, 0.77	1.08	0.61	
External regulation	Total	2.12, 0.92	0.61	−0.45	
	Boys	2.06, 0.89	0.67	−0.19	.13[b]
	Girls	2.19, 0.94	0.54	−0.7	
Amotivation	Total	1.78, 0.99	1.32	1.08	
	Boys	1.68, 0.95	1.58	2.08	.02[b*]
	Girls	1.88, 1.02	1.09	0.35	g = 0.20
Proportion of ways traveled actively	Total	0.62, 0.31	−0.32	−0.99	
	Boys	0.66, 0.30	−0.47	−0.78	.001[b*]
	Girls	0.58, 0.32	−0.16	−1.13	g = 0.26
Proportion of ways traveled passively	Total	0.38, 0.31	0.32	−0.99	
	Boys	0.34, 0.30	0.47	−0.78	.001[b*]
	Girls	0.42, 0.32	0.16	−1.13	g = 0.26

SD = standard deviation.
  [a] Welch's test was performed when Levene's test (p <.05) indicated unequal variances of groups.
  [b] two-sided *t*-test was performed when Levene's test (p >.05) indicated equal variances of groups.
  * significant difference between girls and boys with p <.05; for significant differences effect sizes (Hedges' g) are presented below the p-value.

3.5. Association of behavioral regulations and active travel behavior in adolescents

Logistic regressions were performed to determine the relationship between intrinsic motivation, integrated regulation, identified regulation, introjected regulation, external regulation, and amotivation on the likelihood of using an active mode of transport. Table 5 provides an overview of the regression parameters from the analysis for the total sample as well as for girls and boys separately.

In the overall sample, the model was significant ($\chi^2 = 273.92$, p <.001) and explained 42.1 % (Nagelkerke R^2) of the variance in AT behavior. Integrated and identified regulation as well as amotivation were significantly related to the likelihood of using an active mode of transport. While an increase in integrated and identified regulation increases the odds of using an active mode of transport, an increase in amotivation results in a decrease in the odds.

For boys, the model was significant ($\chi^2 = 137.99$, p <.001) and explained 41.9 % (Nagelkerke R^2) of the variance in AT behavior. Intrinsic motivation, integrated regulation, introjected regulation and external regulation were not significantly associated with the odds of using an AT mode. Increasing identified regulation was significantly associated with an increase in the odds of using an AT mode, whereas increasing amotivation decreased the odds of using an AT mode.

Table 5
Association between behavioral regulations and traveling active for total, male and female sample.

	Total			Boys			Girls		
	b	OR [95 %CI]	%	b	OR [95 %CI]	%	b	OR [95 %CI]	%
Intrinsic Motivation	-0.07	0.93 [0.82, 1.06]	−6.9	-0.0.9	0.91 [0.75, 1.1]	−9.1	-0.11	0.89 [0.74, 1.08]	−10.8
Integrated Regulation	**0.15***	1.16 [1.01, 1.33]	15.8	0.07	1.07 [0.88, 1.29]	6.9	**0.23***	1.25 [1.03, 1.53]	25.3
Identified Regulation	**0.18****	1.20 [1.05, 1.38]	20.3	**0.34****	1.40 [1.15, 1.71]	40.2	0.07	1.07 [0.88, 1.30]	7.2
Introjected Regulation	0.04	1.04 [0.90, 1.21]	3.9	-0.04	0.96 [0.77, 1.19]	−4.0	0.12	1.12 [0.92, 1.39]	12.6
External Regulation	0.09	1.09 [0.98, 1.22]	9.1	-0.01	0.99 [0.84, 1.17]	−0.8	**0.18***	1.20 [1.03, 1.41]	20.3
Amotivation	**-0.26****	0.77 [0.69, 0.86]	−23.0	**-0.21****	0.81 [0.70, 0.95]	−18.8	**-0.31****	0.73 [0.63, 0.86]	−26.6

Note: Regression analyses were adjusted for age, social support and level of urbanization.
b = regression coefficient; OR = odds ratio, calculated by exp(b); % = percentage decrease or increase of the odds of using an active mode of transport, when the respective regression parameter increases by 1.
* significant regression coefficient with p <.05;
** significant regression coefficient with p <.01.

For girls, the model was significant (χ^2 = 146.45, p <.001) and explained 44.8 % (Nagelkerke R^2) of the variance in AT behavior. The analysis revealed no significant association of intrinsic motivation, identified and introjected regulation with the odds of using an AT mode. An increase in amotivation significantly decreased the odds of using an AT mode, whereas an increase in integrated or external regulation significantly increased the odds.

4. Discussion

The present work sought to gain a better understanding of the relationship between the motivational types proposed within SDT and travel behavior in adolescents with emphasis on the distinction between girls and boys. Thus, we investigated sex/gender differences in behavioral regulation towards AT. To allow a more individualized perspective, we examined the relationship between behavioral regulations and AT behavior in adolescent boys and girls separately.

Prior to proceeding to our main analyses, a CFA was conducted to evaluate the measurement model and to assess whether the responses to the questionnaire aligned with a simplex pattern of associations (i.e., reflective of the continuum of relative autonomy within SDT) (Flake et al., 2017). The obtained fit indices showed an acceptable model fit of the data to the model. Factor loadings were adequate with values ranging from 0.55 (item 7) to 0.89 (item 10). Correlation values among the latent variables were consistent with the theoretical assumptions of the autonomy continuum from SDT (Ryan & Deci, 2017), supported by the presence of the proposed simplex structure of association (Ryan & Connell, 1989). This simplex structure is also evident in the original questionnaire concerned with behavioral regulation in exercise (Markland & Tobin, 2004; Wilson, Rodgers, Loitz, & Scime, 2006). Even though our results suggest high correlations between the three autonomous motivations, this is in line with the findings from the original BR-ACS by Burgueño et al. (2019) and with the Portuguese version of BR-ACS by Marques et al. (2022). Cronbach's alpha and composite reliability values provided support for acceptable internal consistency. Even though AVE values fall below 0.50, convergent validity of the construct is still adequate since composite reliability is higher than 0.60 (Fornell & Larcker, 1981). Invariance analysis across sex/gender for the six-factor structure supports the use of the questionnaire to evaluate sex/gender differences in the behavioral regulations towards AT. This is in line with the original Spanish questionnaire (Burgueño et al., 2019). We conclude that the questionnaire applied in this study is appropriate to assess behavioral regulations towards AT in the sample of German speaking adolescent boys and girls.

The examined sex/gender differences in behavioral regulation showed significantly higher levels of intrinsic motivation and significantly lower levels of amotivation in boys compared to girls. Additionally, boys reported significantly more trips for which they used an active mode of transport than girls. These results support the tenets within SDT that intrinsic motivation (or high quality motivation) is linked to the adoption and execution of the desired behavior whereas amotivation is rather detrimental (Ryan & Deci, 2017). To the best of our knowledge, no previous study has systematically examined sex/gender differences in the behavioral regulations towards the AT context. In the context of PA and exercise, some studies have investigated sex/gender differences (Gillison, Standage, & Skevington, 2006; Lauderdale, Yli-Piipari, Irwin, & Layne, 2015; Luque-Casado, Mayo, Lavín-Pérez, Jiménez, & Del Villar, 2021), however, evidence is rare. Similar to our results, a mixed-methods study based on SDT reported significantly lower levels of PA and autonomous forms of motivation in adolescent girls compared to boys (Luque-Casado et al., 2021). A study among British adolescents revealed that boys who reported significantly more leisure-time exercise than girls, also expressed more intrinsic goals for exercise participation while girls expressed more extrinsic goals (Gillison et al., 2006). In contrast, a study with college students found that, even though males reported more internal motives for PA engagement than females, PA levels were not significantly different between males and females (Lauderdale et al., 2015). This study not only demonstrated sex/gender differences in the behavioral regulations, but also builds on the findings reported by Teixeira et al. (2012) that, depending on sex/gender, the individual regulations

may cause different effects on the respecting behavior. In this sense, a study from Germany showed that different behavioral regulation profiles were associated with different PA levels: girls with a specific combination of intrinsic and external regulations had the highest moderate-to-vigorous PA levels in physical education (Bachner, Sturm, García-Massó, Molina-García, & Demetriou, 2020).

Results from the regression analysis showed that intrinsic motivation had no significant association with AT in the total sample. Although somewhat contradictory to SDT, these findings might originate from the AT context. Specifically, traveling a distance to a certain location is mostly not performed for the pure interest and enjoyment of traveling nor does it offer other attributes inherent to intrinsic motivation (e.g., optimal challenge), yet merely to reach a destination. Thus, extrinsic forms of motivation are highly relevant and applicable to the AT context (e.g., only method of travel, because of health benefits). This issue was also considered by Burgueño et al. (2019) who found that integrated and identified regulation were more beneficial in promoting AT to/from school than intrinsic motivation. White et al. (2018) reported that 32 % of students walk to school because they 'have to' as it is their only form of transport. These authors also found that approximately half of their sample reported experiencing negative affect, feeling forced into the action, and being bored in terms of AT. Such results are consistent with the notion that controlled (or poor quality) forms of motivation yield psychological costs. These issues withstanding, the non-significant relationship in the current work is surprising and should receive attention in further research. Looking at girls and boys separately, the association remains non-significant. This is an important finding that should be considered for intervention development: promoting intrinsic motivation for AT in adolescents might not result in a change of travel behavior.

In contrast to intrinsic motivation, integrated regulation significantly increased the odds for AT in the total sample (15.8 %), which is in line with SDT (Ryan & Deci, 2000). Burgueño et al. (2019) also reported strong positive associations between integrated regulation and AT behavior in adolescence. In our study, integrated regulation in girls showed the strongest positive relation with AT behavior (25.3 %) but only a small and non-significant relationship in boys. This suggests that adolescent girls are more likely to travel actively when they consider themselves as 'that type of person who travels actively' because it fits their values and needs (integrated regulation). Thus, in contrast to boys, it seems important that girls internalize this activity as part of their own identity.

Similar to integrated regulation, and again consistent with SDT, identified regulation significantly increased the odds for AT (20.3 %) when analyzing the total sample. In the separate analyses for boys and girls, the increase in the odds for AT was significant only in boys (40.2 %). Providing a meaningful rationale for AT could be a particularly effective strategy (see SDT behavior change techniques by Teixeira et al. (2020) for more strategies) to increase AT among boys because they are more likely to use an active mode of transport when they personally value its importance. However, based on our results, this strategy would have no effect on AT in girls.

Introjected regulation showed no significant association in the whole sample or in either of the sex/gender subsamples. Considering the theoretic origin of the desire to avoid failure and the resulting wording of the items (see Supplementary 1) to capture introjected regulation, this result might also be attributed to AT in adolescence. As described above, traveling includes the non-optional component of 'must arrive somewhere'. Additionally, adolescents seem to be mostly unaware, on how much PA is needed to achieve a healthy lifestyle (Lago-Ballesteros, García-Pascual, González-Valeiro, & Fernández-Villarino, 2021). Thus, if one manages to reach a destination somehow, adolescents might not perceive choosing a passive mode of transport as 'failure' because one still has achieved to arrive at the desired destination. It should be considered that introjected regulation reached a low AVE value of 0.37, which is still acceptable with a composite reliability value over 0.50, however, this might have contributed to the null finding.

External regulation showed no significant association with AT in the total sample. This was also found in boys. In girls, external regulation increased the odds for AT by 20.3 %. These results suggest that adolescent girls are more likely to travel actively when they are influenced or feel pressured by other people (i.e., feeling forced to undertake the behavior). As they tend to evaluate negative interpersonal responses as more stressful than boys (Rudolph, 2002), the strong relationship of external regulation and AT behavior in order to please others or avoid conflicts, seems plausible. However, the positive relationship between external regulation and AT behavior is contradictory to SDT. Previous research has also reported a non-significant relationship of external regulation and AT to/from school, which is commensurate with our findings from the analysis of the total sample (Burgueño et al., 2019). Again, this emphasizes the importance of sex/gender-sensitive analysis.

In accordance with SDT, amotivation showed the strongest negative association with AT behavior. This association was present in all three regression analyses (total sample: –23.0 %; boys:-18.8 %; girls:-26.6 %). From a theoretical perspective, the negative association of amotivation and AT behavior makes logical sense, as amotivation describes the absence of motivation (Ryan & Deci, 2017). Nevertheless, in previous research, such a relation was not observed (Burgueño et al., 2019).

In summary, the results from the regression analyses emphasize the importance of sex/gender-sensitive analyses. Analyzing the associations of the single behavioral regulations only for the total sample, without differentiating between boys and girls, would have masked the fact that some behavioral regulations are beneficial or disadvantageous for girls but not for boys and vice versa. This suggests that the promotion of some behavioral regulations might not be equally effective among adolescent girls and boys. However, this is the first study to address this issue and the results provide initial indications that need to be further explored.

Meanwhile, our findings have important implications for the development of interventions to promote AT among adolescents. First, interventions should incorporate a sex/gender-sensitive development. Second, interventions concerning AT promotion among adolescent boys should aim to establish AT as a meaningful and important opportunity (identified regulation). Third, interventions designed for adolescent girls should mainly focus on integrating AT as an important part of their personality (integrated regulation). Lastly, external encouragement, especially from family and friends (external regulation), should be considered when designing interventions for girls. With these findings in mind, and in the context of SDT (Ryan & Deci, 2017), it would be interesting to examine whether external regulation yields poor quality experience and wellbeing outcomes in the AT context prior to promoting such contingencies via intervention.

This study has several strengths worth mentioning. First, our study included a nationwide sample of adolescents in Germany, who

are under-researched compared to younger populations and at a high risk regarding physical inactivity. Second, we aimed for a comprehensive analysis of travel behavior among adolescents and covered several important destinations e.g. friends/relatives or shopping destinations, rather than focusing only on the school setting. Third, when analyzing the behavioral regulations, we decided not to collapse single regulations into aggregated measures of controlled and autonomous motivation to allow rich interpretations with great opportunities for tailored interventions. Lastly, we used a questionnaire which was previously proven to be valid in the adolescent population (Burgueño et al., 2019). Because we translated and slightly adapted this questionnaire, we additionally examined the psychometric properties of this tool.

Nevertheless, the study has limitations that need to be addressed. The present investigation is of cross-sectional design and, thus, does not allow conclusions about causation. Further, the purposeful sampling method prevents generalizability of the results. Along with this limitation, a further problem may arise from performing the validation in a single data set, an issue that which has been discussed previously as a limitation by work (Bujang et al., 2018) that our study followed as a guideline. In terms of the CFA, the sample size of 517 participants might have compromised the results somewhat, because a ratio of at least 10 cases per parameter is recommended (Kline, 2015). Nevertheless, the study's sample size exceeds those of comparable studies in this field (e.g., Burgueño et al., 2019; Marques et al., 2022). Further, the assessment of AT behavior was based on the usual mode of transport to the described destinations, which does not account for the frequency these ways were undertaken. Additionally, the assessments were based on self-reported data, which are prone to bias due to its subjective nature and the corresponding issues of social desirability and recall bias. The aspect of common-method variance should also be kept in mind. Another critical aspect concerns the data collection which took place during the COVID-19 pandemic. We cannot estimate the extent to which the COVID-regulations might have impacted the usual choice of transportation mode, however, data collection was conducted in June 2021 when restrictions were low.

5. Conclusion

Sex/gender differences in AT behavior and behavioral regulations for AT reflected SDT assumptions that more autonomous forms of motivation support the adoption and execution of the respective behavior. However, when examining the relationships of the individual behavioral regulation types with AT in adolescents, results were brought to light that do not completely match the SDT. Presumably, the context of AT is responsible for these results. When designing interventions or assessing motivational constructs concerning AT promotion, further research should take these findings into account by acknowledging the purpose of AT to reach a destination. Further, the disparities found between adolescent boys and girls in the association of the individual behavioral regulations on AT are particularly noteworthy. These results emphasize the need to develop tailored interventions that address to the different needs of girls and boys. This could substantially contribute to developing effective and target group specific interventions to promote AT among adolescent boys and girls.

CRediT authorship contribution statement

Denise Renninger: Conceptualization, Methodology, Formal analysis, Writing – original draft, Writing – review & editing. **Anne Kelso:** Methodology, Writing – review & editing. **Anne K. Reimers:** Methodology, Writing – review & editing, Project administration. **Isabel Marzi:** Methodology, Writing – review & editing. **Franziska Beck:** Methodology, Writing – review & editing. **Eliane S. Engels:** Methodology, Writing – review & editing. **Martyn Standage:** Methodology, Writing – review & editing. **Yolanda Demetriou:** Conceptualization, Methodology, Writing – review & editing, Supervision, Project administration.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.trf.2022.09.015.

References

Aranda-Balboa, M. J., Huertas-Delgado, F. J., Herrador-Colmenero, M., Cardon, G., & Chillón, P. (2020). Parental barriers to active transport to school: A systematic review. *International Journal of Public Health, 65*(1), 87–98. https://doi.org/10.1007/s00038-019-01313-1

Bachner, J., Sturm, D. J., García-Massó, X., Molina-García, J., & Demetriou, Y. (2020). Physical Activity-Related Profiles of Female Sixth-Graders Regarding Motivational Psychosocial Variables: A Cluster Analysis Within the CReActivity Project. *Frontiers in Psychology, 11*(3151). https://doi.org/10.3389/fpsyg.2020.580563

Blanz, M. (2021). *Forschungsmethoden und Statistik für die Soziale Arbeit: Grundlagen und Anwendungen* (2 ed.). Stuttgart: Kohlhammer Verlag.

Bujang, M. A., Sa'at, N., Sidik, T. M. I. T. A. B., & Joo, L. C. (2018). Sample Size Guidelines for Logistic Regression from Observational Studies with Large Population: Emphasis on the Accuracy Between Statistics and Parameters Based on Real Life Clinical Data. *The Malaysian journal of medical sciences : MJMS, 25*(4), 122–130. https://doi.org/10.21315/mjms2018.25.4.12

Bull, F. C., Al-Ansari, S. S., Biddle, S., Borodulin, K., Buman, M. P., Cardon, G., … Willumsen, J. F. (2020). World Health Organization 2020 guidelines on physical activity and sedentary behaviour. *Br J Sports Med, 54*(24), 1451–1462. https://doi.org/10.1136/bjsports-2020-102955

Burchartz, A., Oriwol, D., Kolb, S., Schmidt, S. C. E., Wunsch, K., Manz, K., … Woll, A. (2021). Comparison of self-reported & device-based, measured physical activity among children in Germany. *BMC Public Health, 21*(1), 1081. https://doi.org/10.1186/s12889-021-11114-y

Burgueño, R., González-Cutre, D., Sevil-Serrano, J., Herrador-Colmenero, M., Segura-Díaz, J. M., Medina-Casaubón, J., & Chillón, P. (2019). Understanding the motivational processes involved in adolescents' active commuting behaviour: Development and validation of the Behavioural Regulation in Active Commuting to and from School (BR-ACS) Questionnaire. *Transportation Research Part F: Traffic Psychology and Behaviour, 62*, 615–625. https://doi.org/10.1016/j.trf.2019.02.016

Burgueño, R., González-Cutre, D., Sevil-Serrano, J., Herrador-Colmenero, M., Segura-Díaz, J. M., Medina-Casaubón, J., & Chillón, P. (2020). Validation of the Basic Psychological Need Satisfaction in Active Commuting to and from School (BPNS-ACS) Scale in Spanish young people. *Journal of Transport & Health, 16*, Article 100825. https://doi.org/10.1016/j.jth.2020.100825

Carlin, A., Murphy, M. H., & Gallagher, A. M. (2016). Do Interventions to Increase Walking Work? A Systematic Review of Interventions in Children and Adolescents. *Sports medicine (Auckland. N.Z.), 46*(4), 515–530. https://doi.org/10.1007/s40279-015-0432-6

Chen, F. F. (2007). Sensitivity of Goodness of Fit Indexes to Lack of Measurement Invariance. *Structural Equation Modeling: A Multidisciplinary Journal, 14*(3), 464–504. https://doi.org/10.1080/10705510701301834

Corder, K., Winpenny, E., Love, R., Brown, H. E., White, M., & Sluijs, E.v. (2019). Change in physical activity from adolescence to early adulthood: A systematic review and meta-analysis of longitudinal cohort studies. *British Journal of Sports Medicine, 53*(8), 496. https://doi.org/10.1136/bjsports-2016-097330

Costa, J., Adamakis, M., O'Brien, W., & Martins, J. (2020). A Scoping Review of Children and Adolescents' Active Travel in Ireland. *International journal of environmental research and public health, 17*(6), 2016. https://doi.org/10.3390/ijerph17062016

Eggs, J., Follmer, R., Gruschwitz, D., Nobis, C., Bäumer, M., & Pfeiffer, M. (2018). *Mobilität in Deutschland - MiD Methodenbericht. Studie vom infas, DLR, IVT und infas 360 im Auftrag des Bundesministers für Verkehr und digitale Infrastruktur.* Bonn, Berlin: www.mobilität-in-deutschland.de Retrieved from www.mobilität-in-deutschland.de.

Flake, J. K., Pek, J., & Hehman, E. (2017). Construct Validation in Social and Personality Research: Current Practice and Recommendations. *Social Psychological and Personality Science, 8*(4), 370–378. https://doi.org/10.1177/1948550617693063

Fornell, C., & Larcker, D. F. (1981). Evaluating structural equation models with unobservable variables and measurement error. *Journal of marketing research, 18*(1), 39–50.

Fox, J., & Weisberg, S. (2019). *An R Companion to Applied Regression* ((Third ed.).). Thousand Oaks, CA: sage.

Gillison, F. B., Standage, M., & Skevington, S. (2006). Relationships among adolescents' weight perceptions, exercise goals, exercise motivation, quality of life and leisure-time exercise behaviour: A self-determination theory approach. *Health Education Research, 21*(6), 836–847. https://doi.org/10.1093/her/cyl139

Guthold, R., Stevens, G. A., Riley, L. M., & Bull, F. C. (2020). Global trends in insufficient physical activity among adolescents: A pooled analysis of 298 population-based surveys with 1.6 million participants. *The Lancet Child & Adolescent. Health, 4*(1), 23–35. https://doi.org/10.1016/S2352-4642(19)30323-2

Hair, J. F., Anderson, R. E., Babin, B. J., & Black, W. C. (2010). *Multivariate data analysis: A global perspective* (Vol. 7). Upper Saddle River: Pearson.

Haug, E., Smith, O. R. F., Bucksch, J., Brindley, C., Pavelka, J., Hamrik, Z., … Sigmundová, D. (2021). 12-Year Trends in Active School Transport across Four European Countries—Findings from the Health Behaviour in School-Aged Children (HBSC) Study. *International journal of environmental research and public health, 18*(4), 2118. https://doi.org/10.3390/ijerph18042118

Henriques-Neto, D., Peralta, M., Garradas, S., Pelegrini, A., Pinto, A. A., Sánchez-Miguel, P. A., & Marques, A. (2020). Active Commuting and Physical Fitness: A Systematic Review. *International journal of environmental research and public health, 17*(8), 2721. https://doi.org/10.3390/ijerph17082721

Howard, J. L., Gagné, M., Van den Broeck, A., Guay, F., Chatzisarantis, N., Ntoumanis, N., & Pelletier, L. G. (2020). A review and empirical comparison of motivation scoring methods: An application to self-determination theory. *Motivation and Emotion, 44*(4), 534–548. https://doi.org/10.1007/s11031-020-09831-9

Hu, L. t., & Bentler, P. M. (1999). Cutoff criteria for fit indexes in covariance structure analysis: Conventional criteria versus new alternatives. *Structural Equation Modeling: A Multidisciplinary Journal, 6*(1), 1-55. https://doi.org/10.1080/10705519909540118.

Janssen, I., & LeBlanc, A. G. (2010). Systematic review of the health benefits of physical activity and fitness in school-aged children and youth. *International Journal of Behavioral Nutrition and Physical Activity, 7*(1), 40. https://doi.org/10.1186/1479-5868-7-40

Kek, C. C., García Bengoechea, E., Spence, J. C., & Mandic, S. (2019). The relationship between transport-to-school habits and physical activity in a sample of New Zealand adolescents. *Journal of Sport and Health Science, 8*(5), 463–470. https://doi.org/10.1016/j.jshs.2019.02.006

Kelso, A., Linder, S., Reimers, A. K., Klug, S. J., Alesi, M., Scifo, L., … Demetriou, Y. (2020). Effects of school-based interventions on motivation towards physical activity in children and adolescents: A systematic review and meta-analysis. *Psychology of Sport and Exercise, 51*, Article 101770. https://doi.org/10.1016/j.psychsport.2020.101770

Kleszczewska, D., Mazur, J., Bucksch, J., Dzielska, A., Brindley, C., & Michalska, A. (2020). Active Transport to School May Reduce Psychosomatic Symptoms in School-Aged Children: Data from Nine Countries. *International journal of environmental research and public health, 17*(23), 8709. https://doi.org/10.3390/ijerph17238709

Kline, R. B. (2015). *Principles and practice of structural equation modeling* (4th ed.). New York: The Guilford Press.

Lago-Ballesteros, J., García-Pascual, M., González-Valeiro, M.Á., & Fernández-Villarino, M.Á. (2021). Gender Influences on Physical Activity Awareness of Adolescents and Their Parents. *International journal of environmental research and public health, 18*(11), 5707. https://doi.org/10.3390/ijerph18115707

Larouche, R. (2018). Last Child Walking?—Prevalence and Trends in Active Transportation. In R. Larouche (Ed.), *Children's Active Transportation* (pp. 53–75). Elsevier.

Larouche, R., & Ghekiere, A. (2018). An Ecological Model of Active Transportation. In R. Larouche (Ed.), *Children's Active Transportation* (pp. 93–103). Elsevier.

Larouche, R., Saunders, T. J., Faulkner, G. E. J., Colley, R., & Tremblay, M. (2014). Associations Between Active School Transport and Physical Activity, Body Composition, and Cardiovascular Fitness: A Systematic Review of 68 Studies. *Journal of Physical Activity and Health, 11*(1), 206. https://doi.org/10.1123/jpah.2011-0345

Lauderdale, M. E., Yli-Piipari, S., Irwin, C. C., & Layne, T. E. (2015). Gender Differences Regarding Motivation for Physical Activity Among College Students: A Self-Determination Approach. *2015, 72*(5). https://doi.org/10.18666/tpe-2015-v72-i5-4682.

Leslie, E., Kremer, P., Toumbourou, J. W., & Williams, J. W. (2010). Gender differences in personal, social and environmental influences on active travel to and from school for Australian adolescents. *Journal of Science and Medicine in Sport, 13*(6), 597–601. https://doi.org/10.1016/j.jsams.2010.04.004

Luque-Casado, A., Mayo, X., Lavín-Pérez, A. M., Jiménez, A., & Del Villar, F. (2021). Understanding Behavioral Regulation Towards Physical Activity Participation: Do We Need a Paradigm Shift to Close the Gender Gap? *Sustainability, 13*(4), 1683. https://doi.org/10.3390/su13041683

Markland, D., & Tobin, V. (2004). A Modification to the Behavioural Regulation in Exercise Questionnaire to Include an Assessment of Amotivation. *Journal of Sport and Exercise Psychology, 26*(2), 191–196. https://doi.org/10.1123/jsep.26.2.191

Marques, A., Santos, T., Demetriou, Y., Schönbach, D. M. I., Peralta, M., Lagestad, P., … Gouveia, É. R. (2022). Adaptation of the Behavioural Regulation in Active Commuting to School (BR-ACS) Questionnaire in Portuguese Youth. Retrieved from *Children, 9*(2), 182. https://doi.org/10.3390/children9020182.

Marques, A., Santos, T., Gouveia, É. R., Demetriou, Y., Schönbach, D. M. I., Ferrari, G., … Peralta, M. (2021). Translation and Validation of the Basic Psychological Need Satisfaction in Active Commuting to and from School (BPNS-ACS) Scale in Young Portuguese Students. *International journal of environmental research and public health, 18*(24), 13091. https://doi.org/10.3390/ijerph182413091

Marzi, I., Emmerling, S., Demetriou, Y., Bucksch, J., Schulze, C., Brindley, C., & Reimers, A. K. (2020). Interventions Aiming to Promote Active Commuting in Children and Adolescents: An Evaluation From a Sex/Gender Perspective. *Frontiers in Sports and Active. Living, 2*(184). https://doi.org/10.3389/fspor.2020.590857

Mikkelsen, B., Williams, J., Rakovac, I., Wickramasinghe, K., Hennis, A., Shin, H.-R., … Breda, J. (2019). Life course approach to prevention and control of non-communicable diseases. *BMJ, 364*, Article l257. https://doi.org/10.1136/bmj.l257

Milfont, T. L., & Fischer, R. (2010). Testing measurement invariance across groups: Applications in cross-cultural research. *International Journal of Psychological Research, 3*(1), 111–130. https://doi.org/10.21500/20112084.857

Ng, J. Y. Y., Ntoumanis, N., Thøgersen-Ntoumani, C., Deci, E. L., Ryan, R. M., Duda, J. L., & Williams, G. C. (2012). Self-Determination Theory Applied to Health Contexts: A Meta-Analysis. *Perspectives on Psychological Science, 7*(4), 325–340. https://doi.org/10.1177/1745691612447309

Nobis, C., & Kuhnimhof, T. (2018). *Mobilität in Deutschland – MiD Ergebnisbericht. Studie von infas, DLR, IVT und infas 360 im Auftrag des Bundesministers für Verkehr und digitale Infrastruktur (FE-Nr. 70.904/15).* Retrieved from Bonn, Berlin: www.mobilitaet-in-deutschland.de.

Ntoumanis, N., Ng, J. Y. Y., Prestwich, A., Quested, E., Hancox, J. E., Thøgersen-Ntoumani, C., … Williams, G. C. (2021). A meta-analysis of self-determination theory-informed intervention studies in the health domain: Effects on motivation, health behavior, physical, and psychological health. *Health Psychology Review, 15*(2), 214–244. https://doi.org/10.1080/17437199.2020.1718529

Owen, K. B., Smith, J., Lubans, D. R., Ng, J. Y. Y., & Lonsdale, C. (2014). Self-determined motivation and physical activity in children and adolescents: A systematic review and meta-analysis. *Preventive Medicine, 67*, 270–279. https://doi.org/10.1016/j.ypmed.2014.07.033

Panter, J. R., Jones, A. P., & van Sluijs, E. M. (2008). Environmental determinants of active travel in youth: A review and framework for future research. *The international journal of behavioral nutrition and physical activity, 5*, 34. https://doi.org/10.1186/1479-5868-5-34

Pavelka, J., Sigmundova, D., Hamrik, Z., Kalman, M., Sigmund, E., & Mathisen, F. (2017). Trends in Active Commuting to School among Czech Schoolchildren from 2006 to 2014. *Central European Journal of Public Health, 25*(Suppl 1), S21–S25. https://doi.org/10.21101/cejph.a5095

Poitras, V. J., Gray, C. E., Borghese, M. M., Carson, V., Chaput, J.-P., Janssen, I., … Tremblay, M. S. (2016). Systematic review of the relationships between objectively measured physical activity and health indicators in school-aged children and youth. *Applied Physiology, Nutrition, and Metabolism, 41*(6 (Suppl. 3)), 197–239. https://doi.org/10.1139/apnm-2015-0663

R Core Team. (2020). *R: A Language and Environment for Statistical Computing.* Vienna: Austria. Retrieved from https://www.R-project.org/.

Reimers, A. K., Marzi, I., Beck, F., Engels, E., Renninger, D., Buttazzoni, A., … Demetriou, Y. (2022). Active travel behaviour in the family environment: Protocol for the mixed-methods cross-sectional ARRIVE study. *BMJ open, 12*(2), Article e056383. https://doi.org/10.1136/bmjopen-2021-056383

Reimers, A. K., Marzi, I., Schmidt, S. C. E., Niessner, C., Oriwol, D., Worth, A., & Woll, A. (2020). Trends in active commuting to school from 2003 to 2017 among children and adolescents from Germany: The MoMo Study. *European Journal of Public Health, 31*(2), 373–378. https://doi.org/10.1093/eurpub/ckaa141

Revelle, W. (2021). *psych: Procedures for Psychological, Psychometric, and Personality Research.* Retrieved from Evanston, Illinois: https://CRAN.R-project.org/package=psych.

Rudolph, K. D. (2002). Gender differences in emotional responses to interpersonal stress during adolescence. *Journal of Adolescent Health, 30*(4), 3–13. https://doi.org/10.1016/S1054-139X(01)00383-4

Ryan, R. M., & Connell, J. P. (1989). Perceived locus of causality and internalization: Examining reasons for acting in two domains. *Journal of Personality and Social Psychology, 57*(5), 749–761. https://doi.org/10.1037/0022-3514.57.5.749

Ryan, R. M., & Deci, E. L. (2000). Self-determination theory and the facilitation of intrinsic motivation, social development, and well-being. *American Psychologist, 55*(1), 68–78. https://doi.org/10.1037/0003-066X.55.1.68

Ryan, R. M., & Deci, E. L. (2017). *Self-determination theory: Basic psychological needs in motivation, development, and wellness.* Guilford Publications.

Schlund, A., Reimers, A. K., Bucksch, J., Brindley, C., Schulze, C., Puil, L., … Demetriou, Y. (2021). Do Intervention Studies to Promote Physical Activity and Reduce Sedentary Behavior in Children and Adolescents Take Sex/Gender Into Account? A Systematic Review. *Journal of Physical Activity and Health, 18*(4), 461–468. https://doi.org/10.1123/jpah.2020-0666

Schoeppe, S., Duncan, M. J., Badland, H., Oliver, M., & Curtis, C. (2013). Associations of children's independent mobility and active travel with physical activity, sedentary behaviour and weight status: A systematic review. *J Sci Med Sport, 16*(4), 312–319. https://doi.org/10.1016/j.jsams.2012.11.001

Schönbach, D. M. I., Altenburg, T. M., Marques, A., Chinapaw, M. J. M., & Demetriou, Y. (2020). Strategies and effects of school-based interventions to promote active school transportation by bicycle among children and adolescents: A systematic review. *International Journal of Behavioral Nutrition and Physical Activity, 17*(1), 138. https://doi.org/10.1186/s12966-020-01035-1

Schönbach, D. M. I., Brindley, C., Reimers, A. K., Marques, A., & Demetriou, Y. (2020). Socio-Demographic Correlates of Cycling to School among 12-to 15-Year Olds in Southern Germany. *International journal of environmental research and public health, 17*(24), 9269. https://doi.org/10.3390/ijerph17249269

Schönbach, D. M. I., Vondung, C., Hidding, L. M., Altenburg, T. M., Chinapaw, M. J. M., & Demetriou, Y. (2020). Gender Influence on Students, Parents, and Teachers' Perceptions of What Children and Adolescents in Germany Need to Cycle to School: A Concept Mapping Study. *International journal of environmental research and public health, 17*(18), 6872. https://doi.org/10.3390/ijerph17186872

Segura-Diaz, J. M., Rojas-Jimenez, A., Barranco-Ruiz, Y., Murillo-Pardo, B., Saucedo-Araujo, R. G., Aranda-Balboa, M. J., … Chillon, P. (2020). Feasibility and Reliability of a Questionnaire to Assess the Mode, Frequency, Distance and Time of Commuting to and from School: The PACO Study. *International journal of environmental research and public health, 17*(14). https://doi.org/10.3390/ijerph17145039

Sex/Gender Methods Group. Why sex and gender matter in health research synthesis. Retrieved from http://methods.cochrane.org/equity/sex-andgender-analysis.

Smith, M., Ikeda, E., Duncan, S., Maddison, R., Hinckson, E., Meredith-Jones, K., … Mandic, S. (2019). Trends and measurement issues for active transportation in New Zealand's physical activity report cards for children and youth. *Journal of Transport & Health, 15*, 789. https://doi.org/10.1016/j.jth.2019.100789

Springer, K. W., Mager Stellman, J., & Jordan-Young, R. M. (2012). Beyond a catalogue of differences: A theoretical frame and good practice guidelines for researching sex/gender in human health. *Social Science & Medicine, 74*(11), 1817–1824. https://doi.org/10.1016/j.socscimed.2011.05.033

Steene-Johannessen, J., Hansen, B. H., Dalene, K. E., Kolle, E., Northstone, K., Møller, N. C., . . . Consortium, H. (2020). Variations in accelerometry measured physical activity and sedentary time across Europe – harmonized analyses of 47,497 children and adolescents. *International Journal of Behavioral Nutrition and Physical Activity, 17*(1), 38. https://doi.org/10.1186/s12966-020-00930-x.

Szumilas, M. (2010). Explaining odds ratios. *Journal of the Canadian Academy of Child and Adolescent Psychiatry, 19*(3), 227–229.

Teixeira, P. J., Carraça, E. V., Markland, D., Silva, M. N., & Ryan, R. M. (2012). Exercise, physical activity, and self-determination theory: A systematic review. *International Journal of Behavioral Nutrition and Physical Activity, 9*(1), 78. https://doi.org/10.1186/1479-5868-9-78

Teixeira, P. J., Marques, M. M., Silva, M. N., Brunet, J., Duda, J. L., Haerens, L., … Hagger, M. S. (2020). A classification of motivation and behavior change techniques used in self-determination theory-based interventions in health contexts. *Motivation Science, 6*(4), 438–455. https://doi.org/10.1037/mot0000172

Telama, R., Yang, X., Leskinen, E., KankaanpÄÄ, A., Hirvensalo, M., Tammelin, T., … Raitakari, O. T. (2014). Tracking of Physical Activity from Early Childhood through Youth into Adulthood. *Medicine & Science in Sports & Exercise, 46*(5). https://doi.org/10.1249/MSS.0000000000000181

Vasconcellos, D., Parker, P. D., Hilland, T., Cinelli, R., Owen, K. B., Kapsal, N., … Lonsdale, C. (2020). Self-determination theory applied to physical education: A systematic review and meta-analysis. *Journal of Educational Psychology, 112*(7), 1444–1469. https://doi.org/10.1037/edu0000420

White, R. L., Parker, P. D., Lubans, D. R., MacMillan, F., Olson, R., Astell-Burt, T., & Lonsdale, C. (2018). Domain-specific physical activity and affective wellbeing among adolescents: An observational study of the moderating roles of autonomous and controlled motivation. *International Journal of Behavioral Nutrition and Physical Activity, 15*(1), 87. https://doi.org/10.1186/s12966-018-0722-0

Who. (2020). WHO guidelines on physical activity and sedentary behaviour. Retrieved from Genva: https://www.who.int/publications/i/item/9789240015128.

Wilson, P. M., Rodgers, W. M., Loitz, C. C., & Scime, G. (2006). "It's Who I Am Really!' The Importance of Integrated Regulation in Exercise Contexts1. *Journal of Applied Biobehavioral Research, 11*(2), 79–104. https://doi.org/10.1111/j.1751-9861.2006.tb00021.x

3.2 Publication 2: Motivation and Basic Psychological Needs Satisfaction in Active Travel to Different Destinations: A Cluster Analysis with Adolescents Living in Germany

Authors: Denise Renninger, Joachim Bachner, Xavier García-Massó, Javier Molina-García, Anne K. Reimers, Isabel Marzi, Franziska Beck, Yolanda Demetriou

Summary:

In this study, a person-centered approach was employed to identify clusters among adolescents that encompass behavioral regulations and psychological needs toward active travel. A person-centered approach was chosen as it advances the understanding of the co-existence of multiple regulations at the same time (Friederichs, Bolman, Oenema, & Lechner, 2015; Howard et al., 2020; Ryan & Deci, 2020). From a health promotion perspective, this can contribute to developing more tailored interventions by identifying the unique needs of specific groups (Vansteenkiste & Mouratidis, 2016). Using SOM analysis, six clusters were identified from the nine input variables (intrinsic motivation, integrated regulation, identified regulation, introjected regulation, external regulation, amotivation, autonomy satisfaction, competence satisfaction, and relatedness satisfaction). First, the resulting profiles were evaluated based on the theoretical background of SDT, specifically in terms of motivation quantity and quality, as well as corresponding levels of satisfaction of basic psychological needs. Regarding motivation, cluster compositions revealed profiles with unimodal distributions (e.g., profiles characterized by a single dominant regulation with a smoothly decreasing endorsement of regulations in relation to the simplex structure of motivation) and profiles with more equal levels of non-adjacent behavioral regulations. The cluster that featured the highest autonomous types of motivation in combination with low controlled types of motivation and amotivation was found to be most beneficial. In contrast, the clusters with higher controlled types of motivation and amotivation in combination with low autonomous types of motivation showed less favorable travel behavior outcomes. The relevance of the satisfaction of basic psychological needs could only be interpreted to a limited extent, as all six profiles exhibited almost comparable values. Besides assessing differences between general active travel, this publication includes a destination-specific perspective including the association of clusters with travel modes and travel distance to and from school, to

friends/relatives, to shopping opportunities, and to leisure facilities. Further, we assessed associations with age, sex/gender, and BMI. Overall, the findings indicate that the motivational profiles appear relevant to explain travel behavior to a diverse set of destinations regardless of distance or adolescents' sex/gender, age, and weight status.

The manuscript was submitted to *behavioral sciences* in February 2023 and accepted and published in March 2023. *Behavioral sciences* is an international, peer-reviewed, open-access journal (Q2, Impact Factor: 2.6) focusing on psychology, neuroscience, cognitive science, behavioral biology, and behavioral genetics.

Contribution:

Denise Renninger was the leading author of this article and developed the idea of this publication with Yolanda Demetriou. Under the co-authors' consultation, Denise Renninger developed the methodology used in the study. Denise Renninger and Xavier García-Massó performed statistical analysis and visualization of results. Denise Renninger wrote the original draft of the article and made revisions based on the review and editing from all other authors.

Motivation and Basic Psychological Needs Satisfaction in Active Travel to Different Destinations: A Cluster Analysis with Adolescents Living in Germany

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Abstract: Active travel in adolescence contributes to improved health outcomes. Self-Determination Theory suggests that motivation and basic psychological needs influence travel behavior. Person-centered approaches can examine interrelationships of these constructs underlying travel behavior. The aim of this study was to investigate (i) which clusters can be identified in adolescents, (ii) whether clusters explain overall active travel behavior, (iii) whether clusters were associated with travel mode to various destinations or distance, and (iv) whether differences across clusters appear regarding sex/gender, age, and weight status. The sample included 517 (263 male, 254 female) adolescents from Germany, aged 11–15. Self-organizing maps analysis identified six clusters from nine input variables: intrinsic motivation, integrated regulation, identified regulation, introjected regulation, external regulation, amotivation, autonomy satisfaction, competence satisfaction, and relatedness satisfaction. The most beneficial cluster regarding active travel demonstrated highest basic psychological needs satisfaction and autonomous motivation with low controlled motivation and amotivation. The most vulnerable cluster was characterized by generally low levels of motivation except for external regulation and amotivation. Clusters were not associated with distance to school, friends/relatives, shopping facilities, or leisure facilities. The findings support the importance of high quality and high quantity of motivation for active travel in adolescents.

Keywords: active transport; commuting; youth; health promotion; behavioral regulation; ARRIVE

1. Introduction

Engaging in regular physical activity (PA) in youth promotes overall health and contributes to the prevention of non-communicable diseases [1–3]. Thus, the global action plan calls for more active people and reduced physical inactivity [4]. However, PA levels among adolescents are alarmingly low worldwide [5,6]. This also applies to Germany, with only four percent (device-base measured PA) or nine percent (self-reported PA) of children and adolescents adhering to the WHO recommendations of 60 min moderate-to-vigorous PA per day [7]. One opportunity to integrate PA on a daily basis is to use an active travel (AT) mode such as walking or cycling to reach destinations [4]. Research emphasizes the importance of AT to increase PA in adolescents [8,9]. Furthermore, adolescents who travel actively can benefit from improved psychological well-being [10,11], physical fitness [9,12], and emotional health [13]. Besides this, AT is a sustainable and environmental-friendly way of traveling [14]. However, AT is declining in many countries all over the world [4]. In

Germany, only a minority of adolescents regularly walk or cycle to destinations such as school [15,16].

This lack of AT in adolescence emphasizes the need for interventions. In order to develop successful interventions, a thorough understanding of modifiable factors and mechanisms of AT is needed. Self-determination theory (SDT) is a widely acknowledged motivational framework for psychological processes and factors that underlie a certain behavior [17,18]. SDT suggests that not only the quantity of motivation but also the quality determines whether a behavior is performed or not [18]. SDT conceptualizes motivation as a construct with two general forms of motivations: intrinsic and extrinsic motivation [17–20]. Intrinsic motivation represents the most autonomous (or self-determined) form of motivation stemming from the inherent pleasure and enjoyment of performing the behavior [18,19]. Extrinsic motivation refers to behaviors that are performed for external reasons rather than for the inherent satisfaction caused by performing the behavior [17,20]. Based on these various (extrinsic) reasons, extrinsic motivation is further distinguished. The most autonomous form of extrinsic motivation is integrated regulation, which means that the person's identity, personal values, and goals align with performing the behavior. A less self-determined (but still autonomous) form is identified regulation, which originates from the importance a person attributes to the behavior. Introjected regulation is defined as a more controlled form of extrinsic motivation, where the behavior is driven by internal pressure to avoid guilt or to improve one's self-esteem. The most controlled form is external regulation, which results from external pressure from other people in order to obtain rewards or to avoid punishments. SDT arranges these different forms of motivation along the continuum of self-determination [17,20]. Decreasing in their degree of self-determination, the three autonomous forms of motivation (intrinsic motivation, integrated regulation, and identified regulation) are followed by the controlled forms (introjected regulation and external regulation). At the non-self-determined end of the continuum, amotivation represents a complete lack of motivation or intention to engage in the behavior [17,20].

SDT proposes that in order to foster self-determination, the satisfaction of the three basic psychological needs (BPNs), autonomy, competence, and relatedness, is fundamental [17,18]. A more self-determined form of motivation increases the likelihood of performing or maintaining a certain behavior. In PA settings, previous research concerning adolescents supports the positive association of autonomous motivation and PA or exercise [21,22] as well as the positive effect of BPNs satisfaction on PA [23,24]. Despite these positive effects, SDT has only recently gained recognition in the context of AT. Specifically, research from Spain, Portugal, and Sweden supports the applicability of SDT in the context of AT to/from school [25–29]. Intrinsic motivation, integrated regulation, and identified regulation positively predicted active school travel in Spanish secondary students [25]. The research from Sweden identified similar positive associations of theses autonomous forms of motivation with active school travel and an additional negative association of amotivation with active school travel [29]. However, SDT-based research in relation to different destinations other than school is lacking. Furthermore, theses aforementioned studies provide good examples of the variable-based approaches traditionally used in SDT-based research. Such approaches examine relationships between motivation or BPNs and a behavior (e.g., [21,30–33]). With regard to motivation, this typically involves pitting the different forms of motivation against each other to identify the most beneficial or detrimental one for a specific behavior. By doing so, variable-based approaches are unable to fully incorporate SDT's theoretical conceptualization of motivation, which includes recognizing that behavior can be motivated by multiple reasons simultaneously [20]. Thus, they neglect the notion of the co-existence of different forms of motivation within groups of individual to varying degrees [34]. This supports the call for more person-centered research such as cluster analyses [35]. These kind of approaches can depict the heterogeneity of motivation by capturing the interplay of the single forms within a person [35,36]. Thus, profiles of naturally occurring combinations of different motivational types within groups of people can be identified, which illustrate specific motivational patterns underlying a

behavior [34–36]. Given the theoretically proposed simplex structure of motivation [18,37], a profile with a single dominant form of motivation combined with some endorsement of proximate forms and decreasing endorsement of more distant ones (i.e., displaying an unimodal curve) would be more common than profiles that exhibit matching levels of opposing forms of motivation [36]. Based on SDT, research has been conducted aiming to identify profiles representing groups of people who share certain motivational characteristics regarding, for example, motivation for physical education [38–40], physical activity [41], or exercise [42,43]. Throughout these studies, research identified various clusters that comprised distinct combinations of the different motivational types. This included both clusters that somewhat followed theoretical assumptions by demonstrating either higher levels of controlled and lower levels of autonomous motivation or vice versa and clusters that were characterized by comparable levels in autonomous and controlled motivation.

Person-centered research has also been conducted to identify profiles concerning BPNs satisfaction [41,44,45]. Considering the theoretical perspective that autonomy, competence, and relatedness constitute key nutriments of high quality motivation [18,20], profiles with high BPNs satisfaction would be observed in combination with higher autonomous motivation. Agreeing with SDT, research from physical education found higher autonomous motivation in clusters of students with high BPNs satisfaction compared to clusters of lower BPNs satisfaction [41,45]. However, in clusters of university students, the cluster characterized by mainly extrinsic motives for PA exhibited higher levels of autonomy satisfaction than the cluster of intrinsic motives [44].

These findings, once again, exemplify the ability of person-centered analyses to capture the diverse composition of subgroup characteristics that could not be fully captured using variable-based analyses. More broadly, this enables the identification of particularly vulnerable and resilient groups, and thus can contribute to the production of more tailored intervention programs [35]. With regard to the debate on the heterogeneity of motivation, the person-centered approach may be specifically helpful to gain a better understanding of the motivational mechanisms underlying AT in adolescents. To the best of our knowledge, no previous study has examined SDT-based clusters of AT behavior in adolescents. Thus, this research aims to answer the following research questions:

1. Which clusters comprising motivation and BPNs satisfaction regarding AT behavior can be identified in adolescents? To gain a better understanding of the co-existence of the psychological determinants of AT, clusters will be generated using self-organizing maps (SOM) analysis. The resulting profiles will be evaluated based on the theoretical assumptions of SDT [17,18].

2. Does overall AT behavior differ between the generated clusters? Current variable-based research indicates that both motivation and BPNs satisfaction affect AT behavior [25,26]. Thus, we assume that, if the SOM analysis results in theory-consistent profiles, differences in overall AT behavior between the clusters will be observable. Overall AT behavior should be higher in clusters with higher levels of autonomous motivation and higher BPNs satisfaction compared to clusters with higher levels of controlled motivation or amotivation and lower levels of BPNs satisfaction.

3. Is travel mode or travel distance associated with cluster membership when considering different destinations? Most research on travel behavior has been conducted on travel behavior to and from school [8]. However, adolescents frequently travel to other destinations in everyday life, such as to shopping or leisure facilities [46]. Therefore, we aim to examine whether an association occurs between the number of adolescents who choose an active travel mode and their cluster membership by considering different destinations. Additionally, distance to a destination has been found to strongly influence travel mode choice [47–49]. Accordingly, we will investigate whether the distance traveled to a certain destination differs between clusters and whether this might contribute to explain travel mode choices.

4. Are there differences across the clusters in terms of sex/gender, age, and weight status? Sex/gender and age predicted cluster membership in a study on motivational

profiles in physical education [50]. Additionally, previous research illustrates lower levels of AT in older youth [15] and female adolescents [16]. Further, research suggests a negative association between AT behavior and body-mass-index (BMI) [51,52]. Thus, differences in the distribution of male and female adolescents, age, and weight status might also occur across the clusters.

2. Materials and Methods

2.1. The ARRIVE Study

The present research is conducted within the ARRIVE (Active tRavel behavioR in the famIly enVironmEnt) study. This cross-sectional study aimed to gain a deeper understanding of the social and individual factors that influence adolescents' AT behavior [53]. The study addressed several gaps of current research in AT among youth. Specifically relevant for the present investigation is that ARRIVE focused on travel behavior, including more destinations instead of being restricted to the school domain like most prevailing research [8,53]. Additionally, it addresses the population of adolescents, which is rather under-researched compared to younger children [8,54,55]. A detailed description of the ARRIVE study and all theoretical underpinnings can be found in the study protocol [53]. By exploring SDT-based clusters in the adolescent population, the present study contributes to the overall aim of the ARRIVE study to gain a deeper understanding of the diverse factors involved in the decision-making process on travel mode choice.

2.2. Study Participants

The target population included adolescents aged 11–15 years and one of their parents. In total, 517 parent-adolescent dyads comprise the study's population. In total, 263 boys and 254 girls with a mean age of 13.11 years (male: M_{age} = 13.21 ± 1.33; female: M_{age} = 12.92 ± 1.35) constituted the study sample. Adolescents were from cities with more than 100,000 inhabitants (29.2%), medium-sized towns consisting of 20,000–99,999 inhabitants (17.4%), small towns with 5000–19,999 inhabitants (22.2%), and living areas with less than 5000 inhabitants (30.8%) in Germany. Adolescents' average BMI was 19.23 kg/m^2 (SD = 3.32, N = 405, min = 12.48, max = 34.36). For some adolescents, height or weight was not available, thus BMI was calculated for 405 participants.

2.3. Data Collection

The survey took place in June 2021. The sample was drawn from a nation-wide online panel (forsa.omninet), which is representative of the German population with regard to age, gender, education, and place of residence. The study collected data from adolescents and one of their parents. Parents were recruited purposively, aiming at an approximately equal number of fathers and mothers and approximately equal number of male and female adolescents aged 11–15 years. Parents were initially contacted by telephone, asking if they were interested in participating in the study. Afterwards, they received detailed information on the study aim and a link to the online questionnaire via e-mail. Prior to study participation, parents and adolescents were asked for their consent to participate. Only if consent was provided, participants were able to start the survey. The questionnaire was structured in two sections: parents completed the first part of the questionnaire. After that, parents were asked to let the adolescent fill out the second part on his or her own.

2.4. Measures

2.4.1. Sociodemographic Data

Socio-demographic data was obtained from the parental section of the questionnaire. Parents indicated adolescents' sex/gender, age, height, and weight.

2.4.2. Motivation towards Active Travel

To assess adolescents' motivation towards AT, the items from the Spanish Behavioural Regulation in Active Commuting to and from School (BR-ACS) Questionnaire [25] were

translated into German. Additionally, items were adapted to focus on motivation towards AT in general (no exclusive focus on AT to/from school). Thus, the expression "to and from school" was replaced with "cover a distance". The translation process commenced with the translation of the original BR-ACS by two independent researchers and the discussion of the resulting two translations. After reaching consensus, the items were reviewed by three experts in the field of youth activity behavior and SDT and subsequently retranslated to ensure the consistency of the German items with the original items. The resulting questionnaire was given to four adolescents (two boys, two girls) to evaluate the acceptability and understanding of the questionnaire. Their feedback resulted in the final German version of the BR-ACS which was used in the study.

The questionnaire comprised six subscales that aimed to assess adolescents' intrinsic motivation (four items; e.g., "I cover distances by foot or bike because it's fun"), integrated (four items; e.g., "I cover distances by foot or bike because it fits to who I am"), identified (three items; e.g., "I cover distances by foot or bike because I value the advantages"), introjected (four items; e.g., "I cover distances by foot or bike because I feel guilty when I don't do so") and external regulation (four items; e.g., "I cover distances by foot or bike because other people say I should do so"), and amotivation (four items; e.g., "I don't see the sense of covering distances by foot or bike") regarding AT. Participants responded on a 5-point Likert scale, from 0 (do not agree at all) to 4 (completely agree). For each subscale, a mean value was calculated for each participant. Previous research demonstrated an appropriate fit of the 6-factor model representing the six motivational types in Spanish, Portuguese, and Swedish adolescents, and supported the simplex structure proposed by SDT [25,27,29]. In the present sample, internal consistency coefficients ranged from 0.69 to 0.91.

2.4.3. Basic Psychological Needs Satisfaction towards Active Travel

Adolescents' BPNs satisfaction was assessed using an adapted version of the Spanish Basic Psychological Need Satisfaction in Active Commuting to and from School (BPNS-ACS) Questionnaire [26]. The items were translated into German and adapted in the same way as it was done with the motivational questionnaire. The questionnaire comprised three subscales that aimed to assess adolescents' autonomy (four items, e.g., "I can choose how I cover distances"), competence (four items, e.g., "I feel that I have the necessary skills to cover distances on foot or by bicycle"), and relatedness (four items, e.g., "I feel very comfortable with the people who accompany me") satisfaction regarding AT. The twelve items were answered using a 5-point Likert scale, from 0 (do not agree at all) to 4 (completely agree). For each of the three subscales, a mean value was calculated for each participant. Previous research showed an acceptable fit of the 3-factor model (autonomy, competence, and relatedness) and found that the questionnaire was valid and reliable in a sample of adolescents [26,27]. For the present study, internal consistency coefficients for autonomy, competence, and relatedness satisfaction were 0.75, 0.85, and 0.76, respectively.

2.4.4. Travel Behavior

Adolescents' travel mode (e.g., by bike, by bus, by car, etc.) was assessed for relevant destinations in adolescence [46]: to school, from school, to friends/relatives, to shopping opportunities, and to leisure facilities. The assessment was based on the Mode and Frequency of Commuting To and From School Questionnaire [56] and the Mobility in Germany survey (Mobilität in Deutschland, MiD, [57]). The given answers regarding the usual travel mode on the way to the respective destinations were subsequently categorized into either active (e.g., walking, cycling) or passive (e.g., being driven by car, using public transport). Thus, we obtained a dichotomous variable (active or passive) for each destination. Additionally, travel distance to each destination was assessed. Parents reported the distance to school. Distance to shopping facilities, friends/relatives, and leisure facilities was obtained from adolescents' self-reports. Adolescents were asked to indicate the distance to the respective destinations according to the following categories: less than 500 m, between 500 m and

1 km, between 1 km and 2 km, between 2 km and 3 km, between 3 km and 5 km, and more than 5 km.

To depict adolescents' overall travel behavior, we first calculated the total number of destinations a participant usually reached actively and the total number of destinations reached passively. The adolescents were also asked to report whether they usually visit the different destinations at all. In a next step, we calculated the 'proportion of ways traveled actively' by dividing the total number of destinations a participant usually reached actively by the sum of all destinations a participant reported to travel to.

2.5. Data Analysis

SOM analysis was used to classify participants into clusters and provide profiles according to participants' similarities regarding the input variables [58]. The nine variables intrinsic motivation, integrated regulation, identified regulation, introjected regulation, external regulation, amotivation, autonomy satisfaction, competence satisfaction, and relatedness satisfaction were used as input variables. The SOM analysis was conducted with the Matlab R2018a program (Mathworks Inc., Natick, MA, USA) and the SOM toolbox (version 2.0 beta) for Matlab [59]. The procedure to obtain the SOM contained three steps [58]: network building, initialization, and training. During network building, a neuron network was constructed, by selecting the lattice size of 14 × 8 neurons based on the sample size of this study. Thereby, each neuron is represented by an empty vector with length equal to the number of input variables. Second, during the initialization, a starting weight (-value) is assigned to each neuron. This is performed for each input variable and in two different ways: randomized and linear initialization. In the third step, two training algorithms (i.e., sequential and batch) were applied to modify the initially assigned weights of the neurons [60]. The modification of the neuronal weights in each iteration of the training process is influenced by several factors. After an input vector (representing a study participant's characteristics in the input variables) is introduced to the neuron network, the neurons compete in order to win the input vector. The neuron with the smallest Euclidean distance to the input vector is the winning neuron. Thus, the winning neuron exhibits the weight vector with the closest values to the input vector's values. Subsequently, all neurons in the network adapt their weight values to the values of the input vector [61]. A neuron's ability to adapt, in turn, depends on the learning ratio and the neighborhood function. The learning ratio commences with a high value and decreases as the training proceeds. The neighborhood function maximizes the adaption magnitude of the winning neuron and its closest neighbors and decreases the adaption magnitude of the neurons that are further away in the network. This adaption process repeatedly continues until the training process is completed [58,61]. Due to random procedures included in the SOM analysis (i.e., initialization and entry order of the input vector), this process was iterated 100 times. This increases the odds of finding the best solution to the problem. Finally, 1600 SOMs resulted from the two training algorithms, four neighborhood functions, and two initialization methods (i.e., 100 × 2 × 4 × 2). Topographical and quantization errors (the average Euclidean difference between participants' input vectors and the weight vectors of the neuron that they are assigned to) were multiplied and the map with the minimum error was selected [61,62]. Subsequently, to categorize neurons into groups according to the values of the input variables (intrinsic motivation, integrated regulation, identified regulation, introjected regulation, external regulation, amotivation, autonomy satisfaction, competence satisfaction, and relatedness satisfaction), a k-means method was used. In order to enable a solution that allows reasonable interpretations by avoiding an excessive amount of clusters, the number of clusters was restricted to range between 2 and 10. The final number of clusters was chosen depending on the Davies–Bouldin index [63] (see Figure 1). The resulting clusters represent typical profiles of adolescents with regard to their AT-related behavioral regulation and BPNs satisfaction.
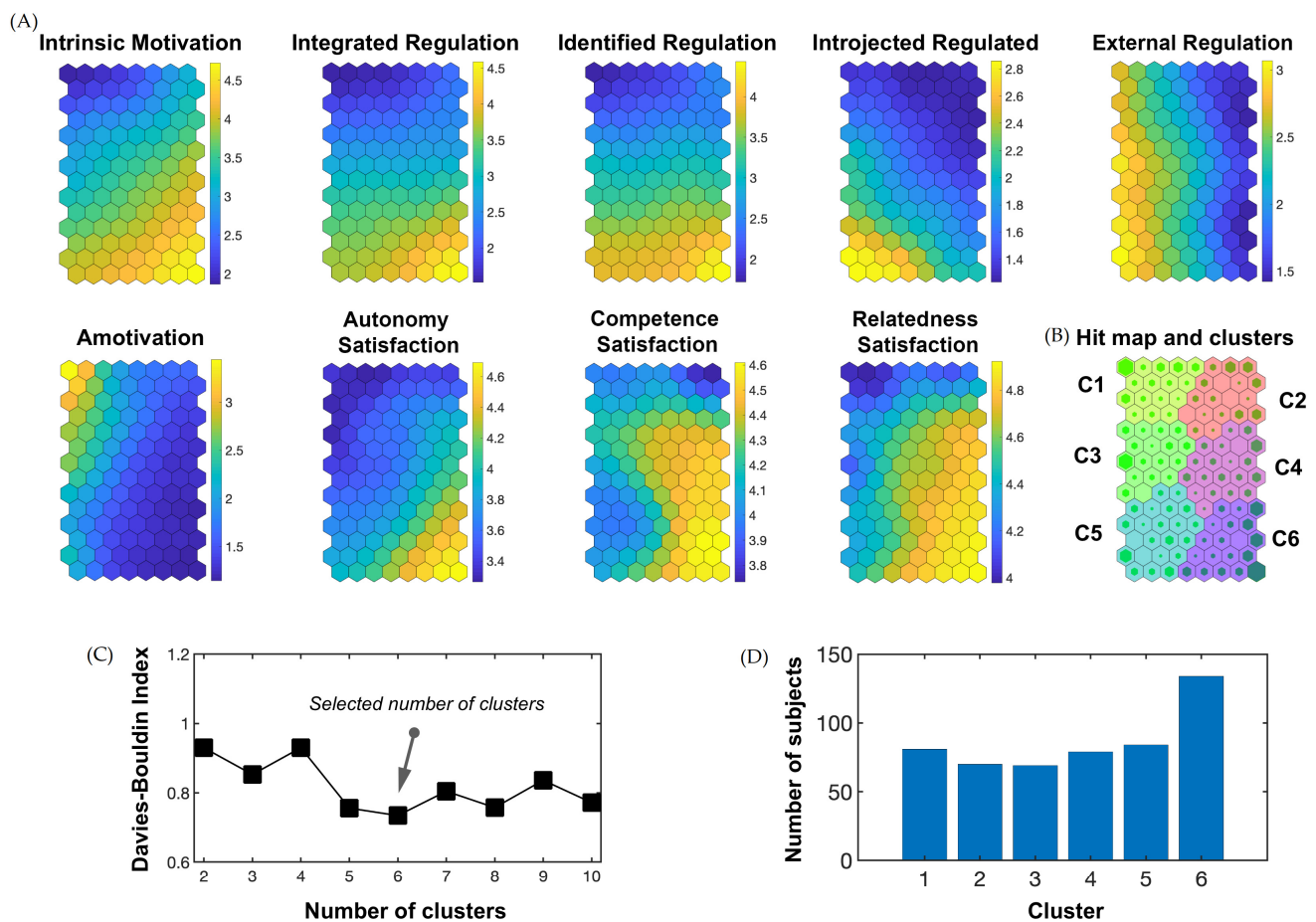
Figure 1. Component planes, clusters (C1–C6), and hits obtained by the SOM analysis. (**A**) Component planes of the nine input variables (intrinsic motivation, integrated regulation, identified regulation, introjected regulation, external regulation, amotivation, autonomy satisfaction, competence satisfaction, and relatedness satisfaction). Yellow neurons indicate comparatively high values; dark blue neurons indicate comparatively low values, depending on the sample's distribution. (**B**) Hit map with the six clusters (C1–C6). The bigger the green filling of a neuron, the higher the number of adolescents assigned to the neuron. (**C**) Quantization error according to the possible number of clusters selected. (**D**) Overview on number of participants in every cluster.

Further analyses were conducted with IBM SPSS Statistics 27. Referring to research question 1, differences in the input variables between the identified clusters were tested using Welch's-ANOVA and the Games–Howell post-hoc test (level of significance $p < 0.05$), due to no homogeneity of variances (Levene's tests, $p < 0.05$). Effect sizes were calculated using the adjusted omega squared (est. ω^2) test. To answer research question 2, whether overall AT differed between clusters, differences in the proportion of ways traveled actively were assessed using Welch's-ANOVA and the Games–Howell post-hoc test (level of significance $p < 0.05$) because the assumption of homogeneity of variance was not met (Levene's test, $p < 0.05$). Research question 3 addressed whether travel mode and travel distance were associated with cluster membership, when destinations are considered individually. Association of travel mode and cluster membership was assessed using the Chi-Squared test (level of significance $p < 0.05$); Cremér's V was estimated to indicate effect size according to Cohen [64]. Since adjusted residuals follow a z-distribution, a value of $+/-1.96$ indicated significant differences between the observed number of adolescents using a travel mode (active or passive) to a destination in a cluster and the expected number. Difference between clusters in distance to school was assessed using Welch's-ANOVA (level of significance $p < 0.05$) due to the lack of homogeneity of variance (Levene's test, $p < 0.05$). Association of

distance to friends or relatives, shopping facilities, and leisure facilities with cluster membership was assessed using the Chi-Squared test (level of significance $p < 0.05$); Cremér's V was estimated to indicate effect size according to Cohen [64]. Lastly, to answer research question 4, the Chi-Squared test (level of significance $p < 0.05$) was applied to analyze whether cluster membership was associated with sex/gender. Additionally, differences between the clusters regarding BMI and age were tested by ANOVAs with a significance level of $p < 0.05$.

3. Results

3.1. Cluster Description

The results of the SOM analysis are presented in Figure 1. For each of the nine input variables, component planes were created (Figure 1A) in which neurons are presented as hexagons. Each adolescent remains in the same neuron in each of the nine component planes. Further, participants located in the same neuron exhibit similar values regarding the input variables. Neurons were grouped into clusters (C1, C2, C3, C4, C5, C6), which are presented in different colors in Figure 1B. The quantization error suggested six clusters (Figure 1C). Figure 1D presents how many adolescents were assigned to each cluster ($n_{C1} = 81$; $n_{C2} = 70$; $n_{C3} = 69$; $n_{C4} = 79$; $n_{C5} = 84$; $n_{C6} = 134$).

Welch's-ANOVAs indicated significant difference between clusters in every input variable (intrinsic motivation: $F(5, 217.66) = 209.90$, $p < 0.001$, est. $\omega^2 = 0.67$; integrated regulation: $F(5, 223.34) = 329.77$, $p < 0.001$, est. $\omega^2 = 0.76$; identified regulation: $F(5, 223.83) = 218.63$, $p < 0.001$, est. $\omega^2 = 0.68$; introjected regulation: $F(5, 227.40) = 71.59$, $p < 0.001$, est. $\omega^2 = 0.41$; external regulation: $F(5, 221.70) = 83.98$, $p < 0.001$, est. $\omega^2 = 0.45$; amotivation: $F(5, 208.82) = 72.04$, $p < 0.001$, est. $\omega^2 = 0.41$; autonomy: $F(5, 211.84) = 80.34$, $p < 0.001$, est. $\omega^2 = 0.43$; competence: $F(5, 198.80) = 29.84$, $p < 0.001$, est. $\omega^2 = 0.22$; relatedness: $F(5, 212.04) = 26.69$, $p < 0.001$, est. $\omega^2 = 20$. The means and standard deviations of the nine input variables and for the proportion of ways traveled actively for each of the six clusters are presented in Table 1. Post-hoc comparisons were conducted to examine significant differences in the input variables between the clusters.

In the following, the profiles of the clusters are described based on the distribution of the six motivational types within each cluster and in consideration of the cluster's mean scores in the motivational and BPNs satisfaction variables relative to the mean scores of the complete sample (in each variable).

Cluster 1: Controlled-amotivated—less satisfied. Autonomous forms of motivation and introjected regulation were below the sample's average scores. All average values of autonomous forms of motivation were lowest in this cluster. External regulation was above the sample's average and average amotivation was highest in this cluster. The distribution of the motivational types clearly represented a non-self-determined profile. Satisfaction of all BPNs was below the sample's average.

Cluster 2: Low-autonomously motivated—less satisfied. All autonomous and controlled forms of motivation were below the sample's average. Amotivation was close to the sample's average. The distribution of the motivational types was slightly in favor of the autonomous forms of motivation and specifically of intrinsic motivation. Satisfaction of all BPNs was below the sample's average.

Cluster 3: Mixed moderately motivated—less satisfied. Autonomous forms of motivation were below the sample's average, while controlled forms and amotivation were above. The distribution of the motivational types was balanced. Satisfaction of competence and relatedness were close, yet still below the sample's average. Autonomy satisfaction was below the sample's average.

Cluster 4: Moderate-autonomously motivated—more satisfied. Intrinsic motivation was above the sample's average, and integrated and identified regulation were close to average. Both controlled forms of motivation and amotivation were below the sample's average. Average amotivation was second lowest in this cluster. The distribution was in

favor of the autonomous forms of motivations. Satisfaction of all BPNs was above the sample's average.

Cluster 5: Mixed highly motivated—less satisfied. All autonomous forms of motivation were above the sample's average. Amotivation was close to the sample's average. The distribution of the motivational types tended towards a self-determined profile; however, controlled forms of motivation were also above the sample's average. Satisfaction of all BPNs was below the sample's average.

Cluster 6: High-autonomously motivated—more satisfied. All autonomous forms of motivation were highest in this cluster. Introjected regulation was above the sample's average, while external regulation was below. Adolescents expressed lowest average amotivation in this cluster. Motivational types were clearly distributed towards a self-determined profile. Satisfaction of all BPNs was above the sample's average.

An additional bar chart of the mean values of the input variables of the six clusters is provided in Figure 2 to visualize the motivational distribution, amount of motivation, and BPNs satisfaction within each cluster.

Table 1. Means (standard deviation) and pairwise comparison of SOM input variables and proportion of ways traveled actively for all six clusters and for the total sample.

	Cluster 1	Cluster 2	Cluster 3	Cluster 4	Cluster 5	Cluster 6	Total
Intrinsic Motivation	1.90 (0.70)	3.02 (0.66) [3]	3.09 (0.57) [2]	3.86 (0.58) [5]	3.88 (0.52) [4]	4.51 (0.50)	3.51 (1.05)
Integrated Regulation	1.49 (0.46)	2.20 (0.61)	2.69 (0.53) [4]	2.78 (0.61) [3]	3.64 (0.50)	4.24 (0.62)	3.01 (1.12)
Identified Regulation	1.75 (0.54)	2.27 (0.64)	2.91 (0.55) [4]	3.09 (0.56) [3]	3.77 (0.48)	4.11 (0.66)	3.12 (1.03)
Introjected Regulation	1.30 (0.41) [2,4]	1.25 (0.30) [1,4]	2.03 (0.56) [6]	1.35 (0.39) [1,2]	2.64 (0.81)	1.94 (0.70) [3]	1.78 (0.76)
External Regulation	2.48 (0.98) [5]	1.43 (0.40) [6]	2.91 (0.72) [5]	1.81 (0.70) [6]	2.85 (0.76) [1,3]	1.60 (0.63) [2,4]	2.12 (0.92)
Amotiation	2.88 (1.15) [3]	1.56 (0.62) [5]	2.52 (0.80) [1]	1.21 (0.35) [6]	1.82 (0.98) [2]	1.15 (0.39) [4]	1.78 (0.99)
Autonomy Satisfaction	3.25 (0.81) [2,3]	3.60 (0.72) [1,3,5]	3.40 (0.66) [1,2]	4.00 (0.56) [5]	3.80 (0.48) [2,4]	4.58 (0.42)	3.87 (0.77)
Competence Satisfaction	4.09 (0.98) [2,3,5]	4.37 (0.74) [1,3,5]	4.34 (0.64) [1,2,5]	4.80 (0.32) [6]	4.45 (0.57) [1,2,3]	4.89 (0.23) [4]	4.54 (0.67)
Relatedness Satisfaction	3.97 (0.85) [2,3,5]	3.90 (0.72) [1,3,5]	4.19 (0.69) [1,2,5]	4.60 (0.45) [6]	3.97 (0.65) [1,2,3]	4.57 (0.43) [4]	4.24 (0.69)
Proportion of ways traveled actively (all destinations)	0.47 (0.34) [2,3]	0.54 (0.34) [1,3,4]	0.58 (0.33) [1,2,4,5,6]	0.65 (0.26) [2,3,5,6]	0.69 (0.28) [3,4,6]	0.71 (0.28) [3,4,5]	0.62 (0.31)

Note: Pairwise comparisons between clusters (Games–Howell post-hoc) were significant ($p < 0.05$) except those marked with superscript numbers (1, 2, 3, 4, 5, 6), which indicate non-significant differences to the respective cluster (e.g., Cluster 1, introjected regulation [2,4] = introjected regulation of Cluster 1 is not significantly different from introjected regulation of Cluster 2 or Cluster 4).
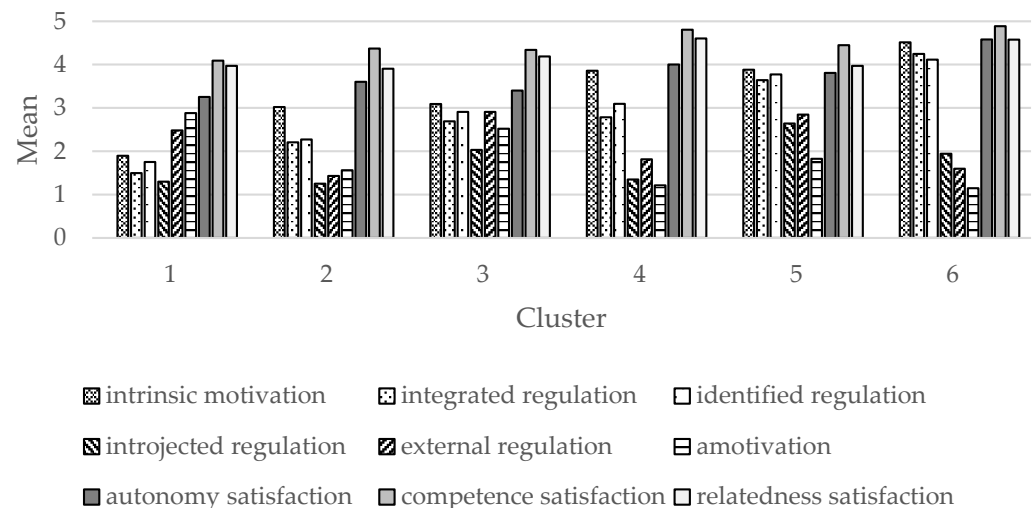
Figure 2. Overview on mean values of SOM input variables across the six clusters.

3.2. Overall Active Travel Behavior

Proportion of ways traveled actively was significantly different between clusters, $F(5, 219.78) = 7.85$, $p < 0.001$, est. $\omega^2 = 0.06$. Post-hoc-tests showed that some clusters did not differ significantly from each other in the proportion of ways traveled actively (see Table 1). C1 had the lowest proportion of ways traveled actively compared to all clusters but was only significantly different from C4–C6. C3 did not differ significantly from any other cluster. Adolescents in C5 or C6 reported significantly higher proportions of ways traveled actively compared to adolescents from C1 and C2.

3.3. Travel Mode and Distance to Specific Destinations

Travel mode was significantly associated with cluster membership for travel to school, $\chi^2 (5) = 20.23$, $p = 0.001$, V = 0.20; travel from school, $\chi^2 (5) = 15.63$, $p = 0.008$, V = 0.17; to friends or relatives, $\chi^2 (5) = 29.43$, $p < 0.001$, V = 0.24; travel to shopping facilities, $\chi^2 (5) = 13.05$, $p = 0.023$, V = 0.16; and travel to leisure facilities, $\chi^2 (5) = 23.37$, $p < 0.001$, V = 0.22. For travel mode to school, from school, to friends or relatives, and to leisure facilities, adjusted residuals exceeded the threshold of +/−1.96 in C1 and C6. Across those destinations, significantly more adolescents than expected used a passive travel mode in C1, while significantly more adolescents than expected used an active travel mode in C6. Additionally, adjusted residuals exceeded +/−1.96 in C5 for AT to school. Thus, in C5, more adolescents than expected traveled to school actively. Regarding travel mode to shopping facilities, adjusted residuals exceeded the threshold of +/−1.96 only in C2, indicating that significantly more adolescents than expected used a passive travel mode. Across all destinations, a similar trend was observable: the percentage of adolescents traveling actively increases from C1 to C6, while it decreases for passive travel. Detailed information on count, expected count, percentage values, and adjusted residuals for travel mode to the various destinations are presented in the supplementary material (Table S1).

There was no significant difference in distance to school between clusters, $F(5, 213.58) = 1.28$, $p = 0.272$. No significant association was found for cluster membership with distance to friends or relatives, $\chi^2 (25) = 32.54$, $p = 0.143$; with distance to shopping facilities, $\chi^2 (25) = 29.68$, $p = 0.236$; or with distance to leisure facilities, $\chi^2 (25) = 17.01$, $p = 0.881$. The distribution of adolescents across distance categories across the six clusters is provided in the supplementary material as well as mean distance to school per cluster (Table S2).

3.4. Cluster Membership and Sex/Gender, Age, and Weight Status

Table 2 shows the respective number of boys and girls as well as mean age and BMI of the adolescents in each cluster. Adolescents' weight status was assessed in 405 participants. No significant difference appeared between clusters and age, $F(5, 511) = 1.49$, $p = 0.192$; or BMI, $F(5, 399) = 0.70$, $p = 0.627$. Further, association of sex/gender and cluster membership, $\chi^2 (5) = 7.30$, $p = 0.20$ was not significant.

Table 2. Description of the clusters by sex/gender, age, and weight status.

	N	Male/Female	Age *	BMI *
Total	517 (100%)	263 (50.9%)/254 (49.1%)	13.11 (1.33)	19.23 (3.32)
Cluster 1	81 (15.7%) [a]	31 (38.3%)/50 (61.7%) [b]	13.11 (1.26)	19.55 (3.47)
Cluster 2	70 (13.5%) [a]	36 (51.4%)/34 (48.6%) [b]	13.31 (1.46)	19.18 (3.12)
Cluster 3	69 (13.3%) [a]	37 (53.6%)/32 (46.4%) [b]	13.06 (1.36)	19.31 (4.04)
Cluster 4	79 (15.3%) [a]	43 (54.4%)/36 (45.6%) [b]	12.86 (1.32)	19.27 (2.93)
Cluster 5	84 (16.2%) [a]	41 (48.8%)/43 (51.2%) [b]	12.85 (1.33)	18.54 (2.75)
Cluster 6	134 (25.9%) [a]	75 (56.0%)/59 (44.0%) [b]	13.17 (1.34)	19.41 (3.45)

* Age and BMI: Data are expressed as mean and standard deviation. [a] Percentage refers to total amount of participants (N = 517). [b] Percentage of male and female adolescents referring to the total amount of participants assigned to the respective cluster.

4. Discussion

This study aimed to explore naturally occurring profiles in adolescents with regard to motivation and BPNs satisfaction in AT. Using SOM analysis, six clusters were identified based on the six different motivational types (amotivation, external regulation, introjected regulation, identified regulation, integrated regulation, and intrinsic motivation) and the satisfaction of the three BPNs (autonomy, competence, relatedness). The clusters were used to explain differences in AT behavior among adolescents. Additionally, we compared the characteristics (i.e., sex/gender, age, and weight status) of adolescents in each cluster. Before discussing the findings, it is worth reflecting upon the potential problem of reification described by Vansteenkiste and Mouratidis [35] regarding the person-centered approach used. Even though every adolescent is categorized by the psychological characteristics of the specific cluster, it is important to note that some adolescents are more prototypical than others. Thus, cluster membership might better be understood as probability than determination [35]. This should be kept in mind throughout the following discussion of results.

First, concerning research question 1, the clusters are regarded against the theoretical background of SDT [17,18,20]. The six identified clusters were distinct in the composition of the motivational characteristics. To a varying extend, the motivational pattern for AT in C2, C4, and C6 tended towards an autonomous profile focusing on the self-determined end of the continuum. C6 exhibited the most prototypical profile in terms of an unimodal distribution of motivation for AT [36]. C4 and C2 did not completely align to the proposed simplex structure of motivation [18,37], however, the overall impression was still autonomous (see Figure 2). C1 presented a profile of overall low quantity motivation for AT, which also showed a tendency toward the non-self-determined end of the continuum and thus was classified as controlled. In this case, the particularly high values of amotivation explain the low level of motivation in this profile, because according to definition, amotivation represents the lack of motivation [18]. C3 demonstrated a profile of mixed motivation for AT with comparable levels in all forms of motivation. In C5, the motivational distribution tended towards a more self-determined profile, however, controlled types of motivation were also high. Thus, no clear focus could be identified, leading to the impression of a mixed motivated profile. C3 and C5 exemplify that AT behavior in adolescents could be regulated by autonomous and controlled motivation simultaneously. Overall, our findings suggest the existence of distinct motivational profiles among adolescents regarding AT, including profiles characterized by a mainly autonomous or controlled pattern, as well as profiles with a more heterogeneous motivational distribution. Our findings are supported by research from diverse backgrounds, investigating motivation via person-centered approaches. Throughout different studies, profiles with unimodal curves were identified, as well as profiles that substantiate the heterogeneity of motivation [38–40,42,50,65,66].

Further, SDT assumes higher satisfaction of the BPNs as precondition for the autonomous forms of motivation [17,18]. In our study, all clusters showed comparatively high levels of BPNs satisfaction towards AT (see Table 1 and Figure 2). Overall, BPNs satisfaction was significantly higher in C4 and C6, both of which demonstrated high values in the autonomous forms of motivation and corresponding low values in the controlled forms and amotivation. This is congruent with the assumptions of SDT that BPNs satisfaction fosters autonomous forms of motivation [17]. Likewise, person-centered studies found that BPNs satisfaction was higher in clusters that expressed higher values in autonomous motivation [41] or were rated as high quality profiles [38,45]. However, C5 also exhibited high values in autonomous motivation but lower satisfaction of the BPNs compared to C4 or C6. The higher values of the controlled forms of motivation in C5 compared to C4 and C6 might yet be explained by the lower BPNs satisfaction in C5. Nevertheless, all clusters demonstrated high levels of BPNs satisfaction and differences between clusters in the BPNs were small (even though sometimes statistically significant, effect sizes were small), especially regarding competence and relatedness. Thus, satisfaction of the BPNs seems to play a minor role for the motivation for AT in adolescents.

Regarding research questions 2 and 3, the clusters are used to explain the difference in overall AT and travel mode choice to the individual destinations. Concerning BPNs satisfaction in AT, the previously mentioned high values across all clusters limit the explanatory possibilities with regard to AT behavior. Therefore, in the following, the explanation for differences in AT behavior is based primarily on the motivational patterns of the clusters. Nevertheless, it needs to be considered, that variable-based research found a positive association of BPNs satisfaction with AT to and from school [26]. This stresses the need for more person-centered research explicitly focused on BPNs in AT.

Even though some clusters did not significantly differ in their AT behavior, two beneficial clusters and one disadvantageous cluster were detected. The two most beneficial clusters for overall AT in adolescents constituted C5 (mixed highly motivated—less satisfied) and C6 (high-autonomously motivated—more satisfied), with a significantly higher proportion of active ways than C1 (controlled-amotivated—less satisfied) and C2 (low-autonomously motivated—less satisfied). Both C5 and C6 had similar levels in overall AT. Additionally, when considering the destinations individually, either C6 or C5 contained the highest percentage of adolescents using an active mode across all destinations. For most destinations (except for travel to shopping facilities), C6 exceeded the expected number of adolescents traveling actively. C5 exceeded this number for travel to school. Even though the motivational distribution showed a more autonomous pattern in C6 compared to C5, the higher values of controlled forms of motivation in C5 might not have been harmful because autonomous forms were appropriately present. Indeed, controlled motivation might have complemented autonomous motivation, resulting in a high motivation quantity. This is in line with person-centered research from physical education and leisure-time PA [40,41]. However, in the context of AT, research from Spain and Sweden assumed that adolescents benefit only from autonomous forms of motivation but not from controlled forms [25,29]. This might be attributed to their variable-centered approach, which assumes a homogeneous population of participants and thus, focuses on the effect of motivation rather than on identifying subgroups in a population with similar motivational characteristics.

Additionally, no significant difference in overall AT behavior was observable between C5 and C6 on the one side and C4 (moderate-autonomously motivated—more satisfied) on the other side. Even though adolescents in C4 exhibited lower levels of autonomous forms of motivation compared to adolescents in C6, C4 still featured an autonomous profile. Nevertheless, overall motivation quantity (i.e., amount of autonomous and controlled motivation) of C4 appeared lower compared to C5 and C6. This might have contributed to the finding that overall AT behavior in C4 was significantly higher than in C1 but not compared to C2. Thus, not only motivation quality (i.e., autonomous pattern) but also quantity (i.e., high autonomous and controlled motivation) was decisive for AT. This is in line with research from physical education, which found that in-class performance was rated equally for students allocated in the autonomously motivated (corresponding to high quality) profile and in the high motivation (corresponding to high quantity) profile [65]. Nevertheless, considering the single destinations, C4 contained a higher percentage of adolescents traveling actively to friends or relatives than C5. This might be attributed to the context of traveling to friends. Presumably, this destination allows more freedom of choice (e.g., when to travel, what to carry) than other destinations. Thus, adolescents might be more likely to decide for their preferred travel mode (e.g., the travel mode for which they are most autonomously motivated). This would indicate the great relevance of a more autonomously motivated and higher satisfied profile in travel contexts with less external constrains.

The most vulnerable profile is represented by C1 (controlled-amotivated—less satisfied). Adolescents in C1 reported significantly lower overall AT compared to adolescents assigned to C4, C5, or C6. Considering the destinations individually, C1 had the highest percentage of adolescents traveling passively to and from school, to friends or relatives, and to leisure facilities. C1 was classified as controlled-amotivated due to the low values in the more self-determined types of motivation and the corresponding higher values in external

regulation and amotivation. The low levels of AT in this cluster are in line with research on students in physical education, which demonstrated lower levels of effort in physical education in more controlled profiles compared to more autonomous profiles [38]. Compared to C5, adolescents allocated to C1 expressed comparable levels of external regulation and even lower values in introjected regulation. Considering the definition of introjected regulation [18], adolescents in this cluster might not yet have internalized external sources of motivation, thus cannot make use of them. Only amotivation was significantly higher in C1 compared to C5. This illustrates the advantage of a profile that expresses a high motivation quantity (i.e., high autonomous and controlled motivation) in combination with low amotivation (i.e., no motivation).

Interestingly, travel distance to school, to friends or relatives, to shopping facilities, and to leisure facilities was not associated with clusters. Therefore, distance did not seem to be a decisive factor in determining adolescents' composition of motivation and BPNs satisfaction. This is conflicting with previous research suggesting that among other factors, adolescents' personal barriers increase with increasing distance [67]. Future research might consider additional factors associated with adolescents' travel behavior (e.g., general PA, neighborhood walkability, safety concerns) and investigate whether such factors differ between clusters.

Regarding research question 4, clusters did not differ in terms of sex/gender, age, or BMI. This supports the idea that the profiles found in our study appear equally in male and female adolescents, and across age and BMI groups. However, regarding age, the non-significant difference may result from the small overall age range of the study population. Concerning sex/gender, previous variable-based approaches have found inconsistent results concerning differences in the individual motivational types [29,68]. Further, even though not significant, the proportion of boys was lowest in C1 (identified as most vulnerable cluster for AT) and highest in C6 (identified as one of the most beneficial clusters for AT). Future research might specifically concern the identification of clusters in boys and girls separately to address this issue. Additionally, it needs to be noted that some data were missing regarding BMI, which might have contributed to the non-significant results. Overall, comparison with other studies' results is difficult due to the diverse settings, variables, and the nature of the person-center approach, which aims to create subgroups from populations. This impedes generalizability of results, thus makes comparisons of studies complicated. Thus, further research, including person-centered analyses, is needed regarding motivation and BPNs satisfaction in AT.

4.1. Implications

Overall, our findings support the applicability of SDT in the context of AT. The cluster solution enabled a better understanding of the SDT-based determinants of AT within adolescents by identifying specifically vulnerable (i.e., adolescents in C1) and resilient (i.e., adolescents in C5 and C6) groups of adolescents. Adolescents who exhibited high quantity of motivation (i.e., high autonomous and controlled motivation) in combination with a tendency towards a higher motivation quality pattern (i.e., a focus towards the self-determined end of the continuum) and highest BPNs satisfaction were most likely to choose an AT mode. Nevertheless, a profile of lower quality due to high levels of controlled motivation seemed to be equally beneficial, as long as autonomous motivations were appropriately present and high values of introjected regulation indicated internalization. Thus, intervention programs should incorporate appropriate behavior-change techniques that aim at creating motivational profiles resembling the profile of C6 (high-autonomously motivated—higher satisfied) or C5 (mixed highly motivated—less satisfied) to enable AT to several destinations in adolescents' daily life. Even if a profile comparable to C6 might not be achieved, a profile resembling C1 should be avoided in any case. More specifically, the amount of both controlled and autonomous forms of motivation should be increased, which subsequently would involve a reduction of amotivation. Ideally, autonomous motivation should exceed controlled motivation, creating high-quality motivation profiles.

However, future research should consider two issues that arise from this finding. First, we found that for destinations offering greater freedom of choice, profiles characterized by a more autonomous distribution of motivation and higher BPNs satisfaction might be more beneficial for choosing an AT mode. Thus, research should put special emphasis on examining diverse destinations that offer varying degrees of freedom to clarify the utility of profiles that differ in their composition of motivation and BPNs satisfaction. This directly relates to the second issue of a potentially poorer quality travel experience, when adolescents face a high number of controlled motivations. Thus, longitudinal studies might contribute to clarify long-term consequences, specifically, whether profiles involving high levels of controlled motivation provide a sustainable way of promoting AT behavior. Taking into account that distance did not differ between clusters highlights the benefits of motivational intervention programs to increase AT to destinations regardless of distance. Further, the association of cluster and travel mode across all examined destinations supports the relevance of the clusters in the context of a variety of destinations in the daily life of youth and not just in the context of school travel. Thus, programs might not necessarily have to be placed in the context of a specific destination, but addressing motivation towards AT in general could enhance AT to several destinations.

4.2. Strength and Limitations

To the best of our knowledge, this was the first study to use a person-centered approach to analyze motivational variables in the context of general AT in adolescence in order to identify typical occurring profiles. A strength of the study was the focus on the adolescent population, which is at risk for physical inactivity and is rather under-researched in the field of AT compared to younger children [54,55]. Assessing AT behavior without focusing exclusively on the school context demonstrated another unique feature of the ARRIVE study compared to most other research in this field [53]. Using a person-centered approach allowed identifying groups of adolescents that share specific combinations of motivational characteristics and helped identify particularly vulnerable adolescents (e.g., C1). Additionally, this analysis acknowledged the assumption that the presence of a single form of motivation does not neglect the absence of any other form [35]. Further, this research benefited from the detailed assessment of intrinsic motivation, integrated regulation, identified regulation, introjected regulation, external regulation, and amotivation, without collapsing them to a single score, which subsequently allowed an understanding of the unique composition within each cluster. Lastly, to assess motivation towards AT and BPNs satisfaction, we made use of questionnaires, which have previously been used and validated in the population of adolescents [25–29]. The limitations of the study included the purposely drawn sample that prevents the generalizability of the results, the exclusive use of self-report data, as well as its cross-sectional design. A longitudinal design could have specifically helped clarify whether the small deviations in BPNs satisfaction contributed to the motivational differences across clusters. Regarding the assessment of motivation and BPNs satisfaction, it needs to be noticed that adolescents did not answer the questionnaires separately for each of the destinations, but once for active travel in general. Future research might consider this and investigate whether these determinants of AT differ when a specific reference to a destination is given. Additionally, AT behavior assessment was based on the usual travel mode which does not take the actual quantity of AT into account. Further, we collapsed several travel modes into a dichotomous variable 'active' and 'passive' travel behavior. Even though research suggests the analysis of the precise modes (e.g., walking, cycling, car etc.) [69], we aimed to enable a more concise presentation of the already detailed analysis. Regarding the assessment of distance to the analyzed destinations, it needs to be mentioned that distance was not assessed uniformly across destinations. While distance to school was assessed via parents and by a continuous variable, distance to the remaining destinations was assessed via adolescents and by categories. Lastly, it is worth mentioning, that the survey was conducted during the COVID-19 pandemic. Even though data were collected in June 2021 when restrictions were low in Germany, we cannot estimate the

extent to which this might have impacted the results. For example, temporary interventions, such as pop-up bicycle lanes, might have temporarily altered travel patterns during the pandemic [70].

5. Conclusions

Based on intrinsic motivation, integrated regulation, identified regulation, introjected regulation, external regulation, amotivation, and the satisfaction of autonomy, competence, and relatedness, the SOM analysis revealed six distinct clusters. The clusters helped to explain differences in AT behavior in adolescents. High motivation quality in combination with high quantity of motivation was most beneficial for AT behavior. Additionally, high levels of controlled forms of motivation did not appear harmful with regard to AT behavior as long as the cluster was still in favor of the autonomous forms. However, future research should investigate whether controlled motivation might provide poor quality experiences and thus do not constitute a sustainable way of promoting AT behavior. The most vulnerable cluster was characterized by low motivation quantity and quality in combination with high levels of amotivation. Interpretation of the relevance of BPNs satisfaction was limited, as the values hardly differed between the clusters. Nevertheless, even slightly higher BPNs satisfaction seemed to increase the chance of a more autonomously motivated profile. Associations of clusters with travel mode across all examined destinations highlight the applicability of our findings to a variety of destinations beyond the school destination. Findings regarding distance suggest that interventions to promote AT in the sense of achieving a high-autonomously motivated profile might be successful regardless of distance to a destination.

References

1. WHO. *WHO Guidelines on Physical Activity and Sedentary Behaviour*; World Health Organization: Geneva, Switzerland, 2020.
2. Janssen, I.; LeBlanc, A.G. Systematic review of the health benefits of physical activity and fitness in school-aged children and youth. *Int. J. Behav. Nutr. Phys. Act.* **2010**, *7*, 40. [CrossRef] [PubMed]
3. Poitras, V.J.; Gray, C.E.; Borghese, M.M.; Carson, V.; Chaput, J.P.; Janssen, I.; Katzmarzyk, P.T.; Pate, R.R.; Connor Gorber, S.; Kho, M.E.; et al. Systematic review of the relationships between objectively measured physical activity and health indicators in school-aged children and youth. *Appl. Physiol. Nutr. Metab.* **2016**, *41*, S197–S239. [CrossRef] [PubMed]
4. WHO. *Global Action Plan on Physical Activity 2018–2030: More Active People for a Healthier World*; World Health Organization: Geneva, Switzerland, 2018.

5.   Guthold, R.; Stevens, G.A.; Riley, L.M.; Bull, F.C. Global trends in insufficient physical activity among adolescents: A pooled analysis of 298 population-based surveys with 1.6 million participants. *Lancet Child Adolesc. Health* **2020**, *4*, 23–35. [CrossRef]
6.   Steene-Johannessen, J.; Hansen, B.H.; Dalene, K.E.; Kolle, E.; Northstone, K.; Møller, N.C.; Grøntved, A.; Wedderkopp, N.; Kriemler, S.; Page, A.S.; et al. Variations in accelerometry measured physical activity and sedentary time across Europe—Harmonized analyses of 47,497 children and adolescents. *Int. J. Behav. Nutr. Phys. Act.* **2020**, *17*, 38. [CrossRef] [PubMed]
7.   Burchartz, A.; Oriwol, D.; Kolb, S.; Schmidt, S.C.E.; Wunsch, K.; Manz, K.; Niessner, C.; Woll, A. Comparison of self-reported & device-based, measured physical activity among children in Germany. *BMC Public Health* **2021**, *21*, 1081. [CrossRef]
8.   Carlin, A.; Murphy, M.H.; Gallagher, A.M. Do Interventions to Increase Walking Work? A Systematic Review of Interventions in Children and Adolescents. *Sports Med.* **2016**, *46*, 515–530. [CrossRef] [PubMed]
9.   Larouche, R.; Saunders, T.J.; Faulkner, G.E.J.; Colley, R.; Tremblay, M. Associations Between Active School Transport and Physical Activity, Body Composition, and Cardiovascular Fitness: A Systematic Review of 68 Studies. *J. Phys. Act. Health* **2014**, *11*, 206. [CrossRef]
10.   Stark, J.; Meschik, M.; Singleton, P.A.; Schützhofer, B. Active school travel, attitudes and psychological well-being of children. *Transp. Res. Part F Traffic Psychol. Behav.* **2018**, *56*, 453–465. [CrossRef]
11.   Kleszczewska, D.; Mazur, J.; Bucksch, J.; Dzielska, A.; Brindley, C.; Michalska, A. Active Transport to School May Reduce Psychosomatic Symptoms in School-Aged Children: Data from Nine Countries. *Int. J. Environ. Res. Public Health* **2020**, *17*, 8709. [CrossRef]
12.   Henriques-Neto, D.; Peralta, M.; Garradas, S.; Pelegrini, A.; Pinto, A.A.; Sánchez-Miguel, P.A.; Marques, A. Active Commuting and Physical Fitness: A Systematic Review. *Int. J. Environ. Res. Public Health* **2020**, *17*, 2721. [CrossRef]
13.   Ramanathan, S.; O'Brien, C.; Faulkner, G.; Stone, M. Happiness in motion: Emotions, well-being, and active school travel. *J. Sch. Health* **2014**, *84*, 516–523. [CrossRef]
14.   Brand, C.; Dons, E.; Anaya Boig, E.; Avila-Palencia, I.; Clark, A.; Nazelle, A.; Gascon, M.; Gaupp-Berghausen, M.; Gerike, R.; Götschi, T.; et al. The climate change mitigation effects of daily active travel in cities. *Transp. Res. Part D Transp. Environ.* **2021**, *93*, 102764. [CrossRef]
15.   Reimers, A.K.; Marzi, I.; Schmidt, S.C.E.; Niessner, C.; Oriwol, D.; Worth, A.; Woll, A. Trends in active commuting to school from 2003 to 2017 among children and adolescents from Germany: The MoMo Study. *Eur. J. Public Health* **2021**, *31*, 373–378. [CrossRef]
16.   Schönbach, D.M.I.; Brindley, C.; Reimers, A.K.; Marques, A.; Demetriou, Y. Socio-Demographic Correlates of Cycling to School among 12-to 15-Year Olds in Southern Germany. *Int. J. Environ. Res. Public Health* **2020**, *17*, 9269. [CrossRef] [PubMed]
17.   Ryan, R.M.; Deci, E.L. Self-determination theory and the facilitation of intrinsic motivation, social development, and well-being. *Am. Psychol.* **2000**, *55*, 68–78. [CrossRef] [PubMed]
18.   Ryan, R.M.; Deci, E.L. *Self-Determination Theory: Basic Psychological Needs in Motivation, Development, and Wellness*; Guilford Publications: New York, NY, USA, 2017.
19.   Deci, E.L.; Ryan, R.M. The "What" and "Why" of Goal Pursuits: Human Needs and the Self-Determination of Behavior. *Psychol. Inq.* **2000**, *11*, 227–268. [CrossRef]
20.   Ryan, R.M.; Deci, E.L. Intrinsic and extrinsic motivation from a self-determination theory perspective: Definitions, theory, practices, and future directions. *Contemp. Educ. Psychol.* **2020**, *61*, 101860. [CrossRef]
21.   Owen, K.B.; Smith, J.; Lubans, D.R.; Ng, J.Y.Y.; Lonsdale, C. Self-determined motivation and physical activity in children and adolescents: A systematic review and meta-analysis. *Prev. Med.* **2014**, *67*, 270–279. [CrossRef]
22.   Teixeira, P.J.; Carraça, E.V.; Markland, D.; Silva, M.N.; Ryan, R.M. Exercise, physical activity, and self-determination theory: A systematic review. *Int. J. Behav. Nutr. Phys. Act.* **2012**, *9*, 78. [CrossRef]
23.   Gunnell, K.E.; Bélanger, M.; Brunet, J. A tale of two models: Changes in psychological need satisfaction and physical activity over 3 years. *Health Psychol.* **2016**, *35*, 167–177. [CrossRef]
24.   Gillison, F.B.; Rouse, P.; Standage, M.; Sebire, S.J.; Ryan, R.M. A meta-analysis of techniques to promote motivation for health behaviour change from a self-determination theory perspective. *Health Psychol. Rev.* **2019**, *13*, 110–130. [CrossRef] [PubMed]
25.   Burgueño, R.; González-Cutre, D.; Sevil-Serrano, J.; Herrador-Colmenero, M.; Segura-Díaz, J.M.; Medina-Casaubón, J.; Chillón, P. Understanding the motivational processes involved in adolescents' active commuting behaviour: Development and validation of the Behavioural Regulation in Active Commuting to and from School (BR-ACS) Questionnaire. *Transp. Res. Part F Traffic Psychol. Behav.* **2019**, *62*, 615–625. [CrossRef]
26.   Burgueño, R.; González-Cutre, D.; Sevil-Serrano, J.; Herrador-Colmenero, M.; Segura-Díaz, J.M.; Medina-Casaubón, J.; Chillón, P. Validation of the Basic Psychological Need Satisfaction in Active Commuting to and from School (BPNS-ACS) Scale in Spanish young people. *J. Transp. Health* **2020**, *16*, 100825. [CrossRef]
27.   Marques, A.; Santos, T.; Gouveia, É.R.; Demetriou, Y.; Schönbach, D.M.I.; Ferrari, G.; Kleszczewska, D.; Dzielska, A.; Peralta, M. Translation and Validation of the Basic Psychological Need Satisfaction in Active Commuting to and from School (BPNS-ACS) Scale in Young Portuguese Students. *Int. J. Environ. Res. Public Health* **2021**, *18*, 13091. [CrossRef]
28.   Marques, A.; Santos, T.; Demetriou, Y.; Schönbach, D.M.I.; Peralta, M.; Lagestad, P.; Martins, J.; Kleszczewska, D.; Dzielska, A.; Gouveia, É.R. Adaptation of the Behavioural Regulation in Active Commuting to School (BR-ACS) Questionnaire in Portuguese Youth. *Children* **2022**, *9*, 182. [CrossRef]

29. Burgueño, R.; Rutberg, S.; Nyberg, L.; Pauelsen, M.; Chillon, P.; Lindqvist, A.-K. Adapting the behavioral regulation in active commuting to and from school questionnaire in Sweden: BR-ACS(SWE). *Transp. Res. Interdiscip. Perspect.* **2022**, *16*, 100721. [CrossRef]

30. Bureau, J.S.; Howard, J.L.; Chong, J.X.Y.; Guay, F. Pathways to Student Motivation: A Meta-Analysis of Antecedents of Autonomous and Controlled Motivations. *Rev. Educ. Res.* **2021**, *92*, 46–72. [CrossRef] [PubMed]

31. Ng, J.Y.; Ntoumanis, N.; Thøgersen-Ntoumani, C.; Deci, E.L.; Ryan, R.M.; Duda, J.L.; Williams, G.C. Self-Determination Theory Applied to Health Contexts: A Meta-Analysis. *Perspect. Psychol. Sci.* **2012**, *7*, 325–340. [CrossRef]

32. Ntoumanis, N.; Ng, J.Y.Y.; Prestwich, A.; Quested, E.; Hancox, J.E.; Thøgersen-Ntoumani, C.; Deci, E.L.; Ryan, R.M.; Lonsdale, C.; Williams, G.C. A meta-analysis of self-determination theory-informed intervention studies in the health domain: Effects on motivation, health behavior, physical, and psychological health. *Health Psychol. Rev.* **2021**, *15*, 214–244. [CrossRef] [PubMed]

33. Vasconcellos, D.; Parker, P.D.; Hilland, T.; Cinelli, R.; Owen, K.B.; Kapsal, N.; Lee, J.; Antczak, D.; Ntoumanis, N.; Ryan, R.M.; et al. Self-determination theory applied to physical education: A systematic review and meta-analysis. *J. Educ. Psychol.* **2020**, *112*, 1444–1469. [CrossRef]

34. Lindwall, M.; Ivarsson, A.; Weman-Josefsson, K.; Jonsson, L.; Ntoumanis, N.; Patrick, H.; Thøgersen-Ntoumani, C.; Markland, D.; Teixeira, P. Stirring the motivational soup: Within-person latent profiles of motivation in exercise. *Int. J. Behav. Nutr. Phys. Act.* **2017**, *14*, 4. [CrossRef] [PubMed]

35. Vansteenkiste, M.; Mouratidis, A. Emerging trends and future directions for the field of motivation psychology: A special issue in honor of Prof. Dr. Willy Lens. *Psychol. Belg.* **2016**, *56*, 118–142. [CrossRef]

36. Howard, J.L.; Gagné, M.; Morin, A.J.S. Putting the pieces together: Reviewing the structural conceptualization of motivation within SDT. *Motiv. Emot.* **2020**, *44*, 846–861. [CrossRef]

37. Ryan, R.M.; Connell, J.P. Perceived locus of causality and internalization: Examining reasons for acting in two domains. *J. Personal. Soc. Psychol.* **1989**, *57*, 749–761. [CrossRef] [PubMed]

38. Bechter, B.E.; Dimmock, J.A.; Howard, J.L.; Whipp, P.R.; Jackson, B. Student Motivation in High School Physical Education: A Latent Profile Analysis Approach. *J. Sport Exerc. Psychol.* **2018**, *40*, 206–216. [CrossRef]

39. Boiché, J.C.S.; Sarrazin, P.G.; Grouzet, F.M.E.; Pelletier, L.G.; Chanal, J.P. Students' motivational profiles and achievement outcomes in physical education: A self-determination perspective. *J. Educ. Psychol.* **2008**, *100*, 688–701. [CrossRef]

40. Ullrich-French, S.; Cox, A. Using Cluster Analysis to Examine the Combinations of Motivation Regulations of Physical Education Students. *J. Sport Exerc. Psychol.* **2009**, *31*, 358–379. [CrossRef]

41. Bachner, J.; Sturm, D.J.; García-Massó, X.; Molina-García, J.; Demetriou, Y. Physical Activity-Related Profiles of Female Sixth-Graders Regarding Motivational Psychosocial Variables: A Cluster Analysis Within the CReActivity Project. *Front. Psychol.* **2020**, *11*, 580563. [CrossRef]

42. Emm-Collison, L.G.; Sebire, S.J.; Salway, R.; Thompson, J.L.; Jago, R. Multidimensional motivation for exercise: A latent profile and transition analysis. *Psychol. Sport Exerc.* **2020**, *47*, 101619. [CrossRef]

43. Gillet, N.; Vallerand, R.J.; Rosnet, E. Motivational clusters and performance in a real-life setting. *Motiv. Emot.* **2009**, *33*, 49–62. [CrossRef]

44. Valenzuela, R.; Codina, N.; Pestana, J.V. University Students' Motives-for-Physical-Activity Profiles: Why They Practise and What They Get in Terms of Psychological Need Satisfaction. *Front. Psychol.* **2020**, *11*, 621065. [CrossRef]

45. Weeldenburg, G.; Borghouts, L.B.; Slingerland, M.; Vos, S. Similar but different: Profiling secondary school students based on their perceived motivational climate and psychological need-based experiences in physical education. *PLoS ONE* **2020**, *15*, e0228859. [CrossRef]

46. Nobis, C.; Kuhnimhof, T. *Mobilität in Deutschland—MiD Ergebnisbericht*; Studie von Infas, DLR, IVT und Infas 360 im Auftrag des Bundesministers für Verkehr und Digitale Infrastruktur (FE-Nr. 70.904/15); infas Institut für Angewandte Sozialwissenschaft GmbH: Bonn, Germany, 2018; Available online: www.mobilitaet-in-deutschland.de (accessed on 17 January 2021).

47. Panter, J.R.; Jones, A.P.; van Sluijs, E.M.F. Environmental determinants of active travel in youth: A review and framework for future research. *Int. J. Behav. Nutr. Phys. Act.* **2008**, *5*, 34. [CrossRef]

48. Mandic, S.; Leon de la Barra, S.; García Bengoechea, E.; Stevens, E.; Flaherty, C.; Moore, A.; Middlemiss, M.; Williams, J.; Skidmore, P. Personal, social and environmental correlates of active transport to school among adolescents in Otago, New Zealand. *J. Sci. Med. Sport* **2015**, *18*, 432–437. [CrossRef] [PubMed]

49. Ikeda, E.; Stewart, T.; Garrett, N.; Egli, V.; Mandic, S.; Hosking, J.; Witten, K.; Hawley, G.; Tautolo, E.S.; Rodda, J.; et al. Built environment associates of active school travel in New Zealand children and youth: A systematic meta-analysis using individual participant data. *J. Transp. Health* **2018**, *9*, 117–131. [CrossRef]

50. Wang, J.C.K.; Morin, A.J.S.; Ryan, R.M.; Liu, W.C. Students' Motivational Profiles in the Physical Education Context. *J. Sport Exerc. Psychol.* **2016**, *38*, 612–630. [CrossRef]

51. Laverty, A.A.; Hone, T.; Goodman, A.; Kelly, Y.; Millett, C. Associations of active travel with adiposity among children and socioeconomic differentials: A longitudinal study. *BMJ Open* **2021**, *11*, e036041. [CrossRef] [PubMed]

52. Lubans, D.R.; Boreham, C.A.; Kelly, P.; Foster, C.E. The relationship between active travel to school and health-related fitness in children and adolescents: A systematic review. *Int. J. Behav. Nutr. Phys. Act.* **2011**, *8*, 5. [CrossRef]

53. Reimers, A.K.; Marzi, I.; Beck, F.; Engels, E.; Renninger, D.; Buttazzoni, A.; Krieger, C.; Demetriou, Y. Active travel behaviour in the family environment: Protocol for the mixed-methods cross-sectional ARRIVE study. *BMJ Open* **2022**, *12*, e056383. [CrossRef] [PubMed]

54. Aranda-Balboa, M.J.; Huertas-Delgado, F.J.; Herrador-Colmenero, M.; Cardon, G.; Chillón, P. Parental barriers to active transport to school: A systematic review. *Int. J. Public Health* **2020**, *65*, 87–98. [CrossRef]

55. Schönbach, D.M.I.; Altenburg, T.M.; Marques, A.; Chinapaw, M.J.M.; Demetriou, Y. Strategies and effects of school-based interventions to promote active school transportation by bicycle among children and adolescents: A systematic review. *Int. J. Behav. Nutr. Phys. Act.* **2020**, *17*, 138. [CrossRef]

56. Segura-Diaz, J.M.; Rojas-Jimenez, A.; Barranco-Ruiz, Y.; Murillo-Pardo, B.; Saucedo-Araujo, R.G.; Aranda-Balboa, M.J.; Herrador-Colmenero, M.; Villa-Gonzalez, E.; Chillon, P. Feasibility and Reliability of a Questionnaire to Assess the Mode, Frequency, Distance and Time of Commuting to and from School: The PACO Study. *Int. J. Environ. Res. Public. Health* **2020**, *17*, 5039. [CrossRef] [PubMed]

57. Eggs, J.; Follmer, R.; Gruschwitz, D.; Nobis, C.; Bäumer, M.; Pfeiffer, M. *Mobilität in Deutschland—MiD Methodenbericht*; Studie vom Infas, DLR, IVT und Infas 360 im Auftrag des Bundesministers für Verkehr und Digitale Infrastruktur; infas Institut für Angewandte Sozialwissenschaft GmbH: Bonn, Germany, 2018.

58. Pellicer-Chenoll, M.; Garcia-Massó, X.; Morales, J.; Serra-Añó, P.; Solana-Tramunt, M.; González, L.-M.; Toca-Herrera, J.-L. Physical activity, physical fitness and academic achievement in adolescents: A self-organizing maps approach. *Health Educ. Res.* **2015**, *30*, 436–448. [CrossRef]

59. Vesanto, J.; Himberg, J.; Alhoniemi, E.; Parhankangas, J. Self-organizing map in Matlab: The SOM Toolbox. In Proceedings of the Matlab DSP Conference, Espoo, Finland, 16–17 November 1999; pp. 16–17.

60. Oliver, E.; Vallés-Pérez, I.; Baños, R.-M.; Cebolla, A.; Botella, C.; Soria-Olivas, E. Visual Data Mining with Self-organizing Maps for "Self-monitoring" Data Analysis. *Sociol. Methods Res.* **2016**, *47*, 492–506. [CrossRef]

61. Estevan, I.; García-Massó, X.; Molina García, J.; Barnett, L.M. Identifying profiles of children at risk of being less physically active: An exploratory study using a self-organised map approach for motor competence. *J. Sport. Sci.* **2019**, *37*, 1356–1364. [CrossRef] [PubMed]

62. Molina-García, J.; García-Massó, X.; Estevan, I.; Queralt, A. Built Environment, Psychosocial Factors and Active Commuting to School in Adolescents: Clustering a Self-Organizing Map Analysis. *Int. J. Environ. Res. Public Health* **2019**, *16*, 83. [CrossRef]

63. Davies, D.L.; Bouldin, D.W. A cluster separation measure. *IEEE Trans. Pattern Anal. Mach. Intell.* **1979**, *1*, 224–227. [CrossRef] [PubMed]

64. Cohen, J. *Statistical Power Analysis for the Behavioral Sciences*, 2nd ed.; Lawrence Erlbaum Associates: New York, NY, USA, 1988.

65. Aelterman, N.; Vansteenkiste, M.; Soenens, B.; Haerens, L. A dimensional and person-centered perspective on controlled reasons for non-participation in physical education. *Psychol. Sport Exerc.* **2016**, *23*, 142–154. [CrossRef]

66. Haerens, L.; Kirk, D.; Cardon, G.; De Bourdeaudhuij, I.; Vansteenkiste, M. Motivational profiles for secondary school physical education and its relationship to the adoption of a physically active lifestyle among university students. *Eur. Phys. Educ. Rev.* **2010**, *16*, 117–139. [CrossRef]

67. Mandic, S.; García Bengoechea, E.; Hopkins, D.; Coppell, K.; Spence, J.C. Adolescents' perceptions of walking and cycling to school differ based on how far they live from school. *J. Transp. Health* **2022**, *24*, 101316. [CrossRef]

68. Renninger, D.; Kelso, A.; Reimers, A.K.; Marzi, I.; Beck, F.; Engels, E.S.; Standage, M.; Demetriou, Y. Motivation and active travel in adolescent girls and boys in Germany—Findings from the ARRIVE study. *Transp. Res. Part F Traffic Psychol. Behav.* **2022**, *90*, 425–437. [CrossRef]

69. Cook, S.; Stevenson, L.; Aldred, R.; Kendall, M.; Cohen, T. More than walking and cycling: What is 'active travel'? *Transp. Policy* **2022**, *126*, 151–161. [CrossRef]

70. Nalmpantis, D.; Vatavali, F.; Kehagia, F. A review of the good practices of active mobility measures implemented by European cities due to the COVID-19 pandemic. *IOP Conf. Ser. Earth Environ. Sci.* **2021**, *899*, 12057. [CrossRef]

3.3 Publication 3: How do adolescents experience the decision-making process on travel mode choice?

Authors: Denise Renninger, Anne K. Reimers, Isabel Marzi, Franziska Beck, Claus Krieger, Yolanda Demetriou

Summary:

The main aim of this publication was to explore the decision-making process on travel mode choice from adolescents' perspective. Although various studies have identified multiple factors associated with active travel, there is a lack of a comprehensive understanding of how these factors are processed by adolescents during decision-making. Thus, we conducted 13 interviews with adolescents aged 11 to 14 and analyzed them using thematic analysis (Braun & Clarke, 2006). A gradual process of decision-making was conceptualized according to the four generated themes: Theme 1) Travel mode is dependent on the context (i.e., situational circumstances and destination); Theme 2) Availability of travel mode choice options is influenced by factors beyond the individual's perceived control; Theme 3) Travel mode choice is dependent on pros and cons assessment; Theme 4) Decision is guided by habitually used travel mode. These themes and the conceptualization of the decision-making process provide various implications for promoting active travel and several entry points for interventions. Specifically, the findings suggest considering contextual circumstances such as day schedules and various destinations as well as individual travel modes (e.g., walking, skating, cycling) rather than addressing 'active travel'. Further, interventions must balance enabling various choices to foster autonomous decision-making and promoting the advantages of active travel modes. Finally, interventions to promote healthy travel behaviors should include practices that encourage conscious processing during decision-making, specifically in habitual travel mode choices.

Although this research did not specifically focus on the processing of motivation during decision-making, the conceptualization of the decision-making process helps to understand the role of motivation during decision-making. Motivation is an individual factor that influences (perceived) availability of travel modes (part of Theme 2) and thus can have an effect on the

pros and cons assessment (part of Theme 3). Moreover, motivation exhibits interactive dynamics with habits (Theme 4) during habit formation and in endeavors of behavior change.

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Contribution:

Denise Renninger was the lead author of this article. She developed the idea for this publication under the consultation of Yolanda Demetriou. Denise Renninger created the interview guide under the consultation of Isabel Marzi, Franziska Beck, and Claus Krieger. Denise Renninger and Isabel Marzi performed data collection through interviews. Denise Renninger analyzed the interviews and developed the presented framework. Denise Renninger wrote the original draft of the article and made revisions based on the review and editing from all other authors.

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Article

How do adolescents experience the decision-making process on travel mode choice?

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Abstract

Active travel can contribute to multiple health benefits in youth. Previous research has identified several factors influencing travel behavior. This study investigates how adolescents process these factors during their decision-making process on travel mode choice. Semi-structured interviews were conducted with 13 adolescents (11–14 years) and analysed using deductive–inductive thematic analysis. Four themes were generated from which the decision-making process on mode choice was conceptualized according to adolescents. The step-by-step process in which travel mode options were gradually reduced, was dependent on the context (Theme 1), the perceived availability of travel mode choice options, which was influenced by factors beyond the individual's perceived control (Theme 2), and on adolescents' pros/cons assessment to identify the most convenient option. Adolescents' habitually used travel mode influenced the decision at several stages throughout the process (Theme 4). To promote healthy travel behaviors, interventions should consider contextual circumstances, balance between enabling autonomous choices and promoting advantages of active travel modes, address individual travel modes and include practices that foster conscious processing of decision-making.

Keywords: active travel, sustainable travel, health promotion, decision-making, transport

BACKGROUND

Active travel (e.g. cycling or walking to destinations) provides a valuable opportunity to integrate physical activity into adolescents' everyday lives (WHO, 2018). Besides holding the potential to increase adolescents' physical activity on a daily basis (Chillón *et al.*, 2010; Larouche *et al.*, 2014), associations with several health outcomes were found. Such outcomes may include improved markers of physical fitness (Henriques-Neto *et al.*, 2020), a more favorable body composition (Larouche *et al.*, 2014), improved cardiovascular health (Chillón *et al.*, 2010; Andersen *et al.*, 2011) and mental well-being (Larouche *et al.*, 2014; Stark *et al.*, 2018), as well as a reduced

prevalence of non-specific psychosomatic complaints (Kleszczewska *et al.*, 2020). These benefits emphasize the importance of active travel in youth. Research has identified multiple correlates with active travel behavior, including complex interactions at environmental, social and individual levels (Panter *et al.*, 2008; Larouche and Ghekiere, 2018; Reimers *et al.*, 2020).

Among other psychosocial constructs on the individual level, self-efficacy toward active travel (Verhoeven *et al.*, 2016; Wang *et al.*, 2017), perceived behavioral control (Zaragoza *et al.*, 2020), or favorable motivational characteristics (Burgueño *et al.*, 2019, 2020) have been found to enable the decision of choosing an active travel mode.

Contribution to Health Promotion

- Active travel (e.g. cycling or walking) offers numerous benefits to physical, mental, and social health while constituting a sustainable way of traveling.
- Worldwide, levels of active travel in adolescents are declining or remain low, which emphasizes the need to understand adolescents' decision-making.
- This article explores how adolescents experience the decision-making process on travel mode choice to enable more tailored interventions to promote active travel behavior.
- The conceptualization of the decision-making process provides various starting points for intervention development.
- Specifically, the description of unconscious and conscious processes contributes to a better understanding of adolescents' decision-making.

Regarding social factors, social modeling, social norms and social support or encouragement from family or friends were also found to influence travel mode (Panter *et al.*, 2010; Ducheyne *et al.*, 2012; Verhoeven *et al.*, 2016). Parent's influence on travel mode is largely grounded in their attitudes toward active travel and their perception of barriers, such as safety concerns, built environment, weather conditions and their child's abilities (Panter *et al.*, 2010; Trapp *et al.*, 2011; Chillón *et al.*, 2014; Esteban-Cornejo *et al.*, 2016; Aranda-Balboa *et al.*, 2019).

Research on the built environment illustrates the importance of adequate infrastructure for choosing an active travel mode (Moran *et al.*, 2016; Smith *et al.*, 2017; Hasanzadeh *et al.*, 2022). Furthermore, distance to a destination largely showed negative associations with active travel and is one of the most documented correlates of active travel (Panter *et al.*, 2008; Pont *et al.*, 2009; Ikeda *et al.*, 2018; Aranda-Balboa *et al.*, 2019). In other studies, however, even when distance was feasible to walk or cycle, no active mode of travel was chosen (Nelson *et al.*, 2008; Westman *et al.*, 2017).

Despite the extensive amount of studies on the determinants of travel behavior, gaining a holistic and comprehensive understanding of all the factors and their relationships remains a challenge (Götschi *et al.*, 2017). In order to visualize such relationships several studies have proposed conceptual frameworks to explain travel behavior including socio-demographic, psychosocial and built environmental factors (Götschi *et al.*, 2017).

At the core, these frameworks position a choice process that is triggered by a demand for traveling to a destination and results in a behavioral response (Alfonzo, 2005; Panter *et al.*, 2008; Burbidge and Goulias, 2009; Götschi *et al.*, 2017). Commonly, this process is understood as the central pathway, during which all influencing factors are considered in order to decide on a travel mode. Some studies have aimed to conceptualize this generic process for travel mode choices (Götschi *et al.*, 2017). However, the existing literature does not provide a conception of how adolescents experience decision-making. Research presenting conceptual frameworks for adolescents' travel behavior mainly examines correlates of active travel by summarizing existing quantitative findings (Panter *et al.*, 2008; Pont *et al.*, 2011; Mitra, 2013; Mandic *et al.*, 2015). This involves identifying the factors that influence travel mode decisions, however, only Panter *et al.* (2008) incorporate a 'decision-making process on [travel] mode choice' within their framework. Nevertheless, the actual process of adolescents' decision-making is not conceptualized. For this purpose, a qualitative approach might be particularly useful to unravel the complexity of the decision-making process underlying adolescents' travel behavior (Clifton and Handy, 2003). Thereby, adolescents' perspective appears decisive. First, health behavior habits are established in adolescence (Mikkelsen *et al.*, 2019). Second, investigating adolescents' experiences might produce different knowledge than examining parental perspectives, as their perceptions might differ (Wilson *et al.*, 2018). Although parents play an essential role in decision-making during childhood (Faulkner *et al.*, 2010; Forsberg *et al.*, 2020), this might progressively change during adolescence due to adolescents' maturation (Blakemore and Robbins, 2012) and their striving for autonomy (Spear and Kulbok, 2004). Existing qualitative research on adolescents' perspectives mainly concerns the experience of specific barriers or facilitators to determine their influence on travel behavior (Simons *et al.*, 2013; Sweeney and Von Hagen, 2016; Møller *et al.*, 2018; White *et al.*, 2018; Roberts *et al.*, 2019; Mindell *et al.*, 2021; Levi and Baron-Epel, 2022; Buttazzoni *et al.*, 2023). Again, adolescents' experience of the decision-making process, in which influencing factors assemble and produce a decision, remains unexplored. To close this gap of knowledge, the aim of the present work is to explore the decision-making process from the perspective of adolescents and to conceptualize this process.

METHODS

To report the methods of this study, we adhere to the consolidated criteria for reporting qualitative studies (COREQ) checklist (Tong *et al.*, 2007).

The ARRIVE study

This research is part of the cross-sectional ARRIVE study (Active tRavel behaviouR in the famIly enVironmEnt). The study comprised a qualitative and a quantitative survey that aimed to gain a better understanding of the mechanisms underlying adolescents' travel mode choices (Reimers *et al.*, 2022). The study received approval from the ethics commission of the Friedrich-Alexander-Universität Erlangen-Nürnberg, Germany (Reg. 249_21 B).

Semi-structured interviews

Interviews were conducted in 2021 from September to November. After participants gave informed consent, an online appointment was scheduled, in order not to unnecessarily compromise health during the Covid-19 pandemic. Participants were asked to attend the meeting from home in an undisturbed place. Since interviewers were unknown to the adolescents they interviewed, participants were first introduced to the interviewing researchers including their interest in the topic. Second, participants were informed again about the procedure, purpose and voluntary nature of the interview. After clarifying the participants' questions, the audio recording started and the interview began. During the interviews, parents were not present.

Two female researchers (D.R. and I.M.) with expertise in children's and adolescents' active travel behavior conducted the interviews. Prior to data collection, both researchers received formal training from an expert in the field. During the training, difficulties, and improvement strategies for interviewing were discussed and practiced until sample interviews were conducted satisfactorily. To ensure consistency in interviewing, interviewers used a previously developed interview guide and discussed each interview post-conduction in terms of issues, adaptations and new perspectives expressed by participants.

To construct the interview guide, two researchers independently mapped topics of interest. Next, the researchers compared both mind maps, discussed similarities and deviations until they reached a consensus. Based on the resulting mind map, various questions were formulated. Under the consultation of two more researchers, unsuitable questions were deleted, remaining questions were gathered and sorted into an interview guide. The interview guide was finalized based on the feedback of an expert in the field and after completing sample interviews, which should ensure the comprehensiveness and appropriateness of questions.

The interview guide depicted two different recently traveled destinations. First, interviewees were asked to 'think about yesterday. Where did you go or drive?'. Adolescents shared their experiences on this trip with yesterday's travel mode and thereafter with the opposite travel mode (active or passive). Key questions concerned the situation before traveling ('Think again exactly about the situation before you [mode of travel]. Can you describe how it came about that you [mode of travel]?; "Tell me about how all went with your parents."), the physical environment ("Think about where you drove/walked along. Can you describe the way exactly so that I can get an idea of it?"), and the social environment ("Did anyone accompany you on the way? Can you describe the situation on the way in detail?"). Then interviewees summarized why they decided for either the passive or active travel mode in the different situations. This was repeated for a second destination. The complete interview guide can be found open access in the study's protocol' (Reimers *et al.*, 2022). After completing the first seven interviews (11:45–20:33 min) and initial analysis, we modified the interview guide to obtain more information on the decision-making experience related to any travel mode without differentiating between active and passive travel. Interviews guided by the modified guide took between 21:01 and 21:48 min. This interview guide is provided in the supplementary material (Supplementary File S1). After ending the interviews and audio recording, sociodemographic data (adolescents' age, school type, residence, and migration background) were collected via parents.

Sampling strategy and participants

We recruited participants through the researcher's social networks ($n = 12$) and social media advertising ($n = 1$). During the recruitment, we adhered to theoretical sampling (Nagl-Cupal, 2013) to enable a balanced sample in terms of sex/gender and environmental conditions (e.g. urban and rural living locations). Furthermore, interviews were analyzed continuously throughout the process of interviewing and recruiting with regard to the research question. Thus, data saturation marked the point at which no further interviews were necessary.

After initial contact with the families, all invited adolescents were willing to participate in the study. This resulted in a total of 13 adolescents aged 11–14 years (7 boys, 6 girls) from secondary schools in Germany. Details on adolescents' sociodemographic are provided in Supplementary File S2.

Data analysis

Four student assistants transcribed interviews verbatim according to Dresing and Pehl (2018) using f4transcript

(audiotranskription.de). To maintain consistency, student assistants received formal training that included familiarization with guidelines and software, and transcription of sample interviews. Researchers answered emerging questions from the student assistants during the transcription phase and checked the resulting text files for correctness. For the purpose of this article, the example quotes were translated from German to English by one researcher (D.R.) and proofread by the remaining authors in terms of appropriateness.

One researcher (D.R.) performed data analysis in f4analyse (audiotranskription.de) using thematic analysis (Braun and Clarke, 2006). The six steps of thematic analysis guided the analysis: data familiarization, initial coding, theme development, theme refinement, defining and naming themes, and writing a report (Braun and Clarke, 2006; Braun *et al.*, 2016). However, this process was reflexive and iterative involving moving forward and backward across the steps. Throughout the analysis, we adhered to the checklist of criteria for good thematic analysis (Braun and Clarke, 2006). We used a combination of a deductive and inductive approach to the data. The deductive part of the research was driven by theoretical assumptions that all factors influencing travel mode choice are processed in the decision-making process on travel mode choice as conceptualized by Panter *et al.* (2008). Exploring the process of decision-making was then performed in a data-driven, inductive way. The research was grounded in a realist's perspective assuming that language enabled adolescents to articulate their experiences and researchers to capture participants' actual experiences.

RESULTS

Adolescents experienced decision-making on travel mode choice as a step-by-step process in which travel mode options were gradually reduced, leading to the final choice. Thematic analysis generated three themes (1–3) that guided this decision-making and one theme (Theme 4) that informed the process at several stages. In the following, we describe the themes and their interactions and include example quotes.

Theme 1: Travel mode choice is dependent on the context

Adolescents did not decide on one exclusive travel mode (e.g. cycling to any destination), but considered every decision in the context of the respective destination they wanted to reach and the current situational circumstances (e.g. time of day, seasonal conditions, day schedules). For example, after asking for the preferred travel mode regardless of destination an adolescent explained how it was impossible to determine a single exclusive travel mode.

It depends, I can't say exactly only one thing. […] when I go to [town name] with my friends, to go shopping or something, I prefer to take the train […]. But […] to get to my friend or something or to the supermarket I prefer to cycle. (Adolescent 11, girl, aged 13)

From the adolescents' perspective, the travel mode choice also depended on the current situational circumstances (e.g. time of day, seasonal conditions, day schedules). For example, day schedules require an adolescent to use a specific travel mode.

Interviewer: And do you get there by bus every time […]? Adolescent: At the moment actually, yes. I do horse riding there on Mondays and Thursdays and I have school in the afternoon on both days and that's why I go there immediately afterwards on both days. (Adolescent 11, girl, aged 13)

Changes in the situational context challenged the habitual response of choosing a particular travel mode to a destination (interaction Theme 4). For example, a boy, who usually drives to school by bus gets driven, when day schedules change.

Oh, I get driven when school starts a little earlier or ends a little later, or because it was a school field trip or something like that. (Adolescent 3, boy, aged 14)

Another quote illustrates how newly created circumstances challenge habitual travel decisions.

We had that once because I somehow misplaced my bus ticket and that's why I always have to buy bus tickets and we thought it would be more effective if I just bought an hourly ticket in the afternoon instead of spending more money on a day ticket for two trips. […] so we did it that way that I am driven every morning. (Adolescent 8, girl, aged 14)

However, habitually choosing a particular travel mode to a specific destination could also facilitate the decision to use the same travel mode in specific circumstances (interaction Theme 4), even though the situation included unfavorable conditions (e.g. bad weather, lack of motivation). Like in the following example, the destination served as a cue that triggered a certain travel mode choice.

I actually always cycle [to school], so even when it rains and stuff. […] I just put on rain pants and a rain jacket and stuff, that's okay. (Adolescent 10, boy, aged 13)

Theme 2: Availability of travel mode choice options is influenced by factors beyond the individual's perceived control

Within the context of destination and situation, adolescents processed the availability of different travel mode options. Adolescents experienced the availability of travel mode options as influenced by various factors such as natural and built environmental factors (e.g. distance, infrastructure), social environmental factors (e.g. parents, siblings, friends), and/or personal factors (e.g. motivation, capabilities).

> *So the distance is very far. And otherwise I would have to cycle. So if I had to cycle I would drive about an hour or an hour and a half.* (Adolescent 6, girl, aged 11)

> *[The way to school] is along the highway, because a bicycle route has been built near us, and I'll be able to cycle there soon, […] then I will definitely cycle more often, because it's just around the corner from me and goes all the way to my school.* (Adolescent 9, boy, aged 13)

> *It was raining very hard, but not in such a way that I would say, come on, I'll go by car now. At first I said that I would walk, but then my parents told me to go by car.* (Adolescent 13, boy, aged 13)

> *There is a bus connection (to leisure activity), but only for me, and then that just doesn't make sense if I leave him (friend) standing there alone […] I guess there's no other option. […] I could still take the bus, then I would have to walk a little bit, but for him there is no option.* (Adolescent 9, boy, aged 13)

> *If she'd say, yes alright I can still imagine to cycle now, which she just doesn't do, […] [then] I would also let myself be persuaded and then also cycle together in the afternoon, but alone and so on, no. Interviewer: […] And could you persuade her, do you think? Adolescent: You know, I have no motivation to do so myself.* (Adolescent 12, girl, aged 13)

Adolescents experience these influencing factors as something given and beyond their control. The following quotes exemplify how adolescents described their inability to influence the availability of choice options as it depended on factors, which they perceived as beyond their control (friend's or sibling's travel mode and own motivation; parents' decision).

> *Most of the time it was just that I either agreed with my friend that we would cycle (to school) […] because I just, I don't know, sometimes I have phases where I*

just want to sit around and do nothing and sometimes I have phases where I'm like: I have to do sports now, otherwise I'll just feel bad somehow. […] And at that time it was just such a phase and then I just said that, or simply because I wanted to go together with my sister or we just wanted to go together. But somehow, well those phases always ended because I then somehow didn't feel like it anymore, or I didn't have the strength anymore, or it was just too exhausting for me.* (Adolescent 11, girl, aged 13)

> *Well, I could also walk, but I just drove with the scooter (to the bus station). […] it depends on whether I'm allowed (by parents) to ride a scooter or not.* (Adolescent 2, boy, aged 12)

Habit operated as an additional influencing factor by limiting the (perceived) availability of options to the habitually chosen travel mode (interaction Theme 4).

> *Interviewer: So what happens at home when you think about planning the way to school tomorrow? Adolescent: That I'm going to cycle. […] I don't really do anything the night before. Interviewer: Because it's clear that you're going by bicycle? Adolescent: Yes!* (Adolescent 1, boy, aged 13)

Theme 3: Travel mode choice is dependent on pros and cons assessment

After adolescents considered the context, they weighed pros and cons of the remaining available travel modes. During this, adolescents either actively engaged in the pros and cons assessment or passively evaluated the outcome. The active assessment was either focused on the advantages of a travel mode that outweighed the disadvantages of others or on the disadvantages of all available travel modes. In the following example, the adolescent focused on the prevailing advantages of cycling to town that made all other available travel mode options appear unattractive.

> *I like to cycle with my friends, because […] we always have to cycle to the city train and then we can cycle directly into town. Going by bus is just so boring at some point. You can also listen to music while cycling. It doesn't make any difference. You can do sports while you're doing it, that's also quite nice. And you're not so tied to the city train. That means you can just go home when you want and you don't have to wait for the city train or bus and stuff.* (Adolescent 4, girl, aged 14)

Overall, adolescents aimed to identify the most convenient or least inconvenient travel mode that they expected to provide the least stressful experience.

Adolescents' individual preferences regarding their general attitude toward a travel mode influenced this identification process, as illustrated in the following example.

> *Well, it's like this, I would also cycle, so I think cycling is better. But I feel that it's just too much for me in the morning, because then I have to get up even earlier […] and that's just stressful for me and then I'd rather, […] take the bus than the car, for example, because that's just better for the environment than the car.* (Adolescent 11, girl, aged 13)

In contrast, another adolescent describes other preferences:

> *I don't really feel like it (going to school by bus). […] because there just, I don't know why, but I don't like going by bus so much and then I'd rather cycle and then just be outside again before I sit in class all the time and stuff.* (Adolescent 10, boy, aged 13)

During the passive evaluation, adolescents mentioned the advantages and disadvantages of travel modes, however, they remained in an observing position without engaging in active decision-making. This was mostly the case, when adolescents felt restricted to only one available travel mode by the influencing factors (Theme 2) or by the habit of choosing this travel mode (interaction Theme 4). For example, when one adolescent felt restricted to his usual travel mode (bus), he did not actively intervene by asking his parents to drive him.

> *Well, by car is difficult in the early morning, because most of the time my parents have to work. And walking wouldn't work either, because it's too far. And cycling would also be too far. That's why the bus was the only option. […] of course it would be nice to be driven every morning, but of course that's not possible and then the bus is actually alright.* (Adolescent 3, boy, aged 14)

The habitual response of choosing a certain travel mode was challenged, when the travel mode was perceived as inconvenient (interaction Theme 4). Furthermore, a rating of inconvenience after the pros and cons assessment could lead adolescents to seek to expand the availability of travel mode options (interaction Theme 2). The interview excerpts in section 'The decision-making process' illustrate this.

Theme 4: Decision is guided by habitually used travel mode

The interviews revealed that on ways to frequently visit destinations, adolescents had already established a habit of using a specific travel mode. This is seen when adolescents describe how they decide on their travel mode to school, which is rather an automatic process than conscious decision-making.

> *Interviewer: Can you tell me why you decided to take the train yesterday? Adolescent: Because I do that every day* (Adolescent 12, girl, aged 13)

> *Interviewer: Is there anything you plan before you have to go (to school)? Adolescent: For four years now it is actually the same, so nothing really changes there. Except maybe with the seasons, when it's cold, then of course I put on something warm.* (Adolescent 3, boy, aged 14)

The decision-making process

In Figure 1, we conceptualize the gradual decision-making process from the presented themes and their interactions.

Excerpts from an interview (adolescent 8, girl, aged 14) exemplify the entire experience of the decision-making process. The way to school constituted the frame of the decision-making (Theme 1). The adolescent recounted perceived restrictions on travel mode options from environmental (distance excluded walking) and personal factors ('cycle lover' identity excluded cycling), which were beyond her control (Theme 2).

> *Adolescent: But I can hardly walk to school in the morning […] because it's too far. […] Interviewer: Would cycling be an option for you? Adolescent: Not really. First of all I don't like cycling and my bicycle is at my dad's place. […] Yeah, I'm not a cycle lover.*

Initially, she was left with traveling by bus as the only available option; however, her perceived inconvenience of bus travel and the loss of the bus ticket challenged this habit (interaction Themes 1 and 4). Additionally, the adolescent perceived several disadvantages (costly and stressful experience) of traveling by bus compared to the advantages (later departure, less stressful, convenient compatibility with mother's work) of being driven by car (Theme 3).

> *Adolescent: It's (driving by car) just not as stressful as when I take the bus in the morning. […] And I don't have to get up as early as if I took the bus, and well, I feel it's quieter than with all the people. Interviewer: Alright, don't you like to be around people? Adolescent: No. Interviewer: […] does your mom combine that with her way to work […]? Adolescent: She, works […] somewhat close to my*
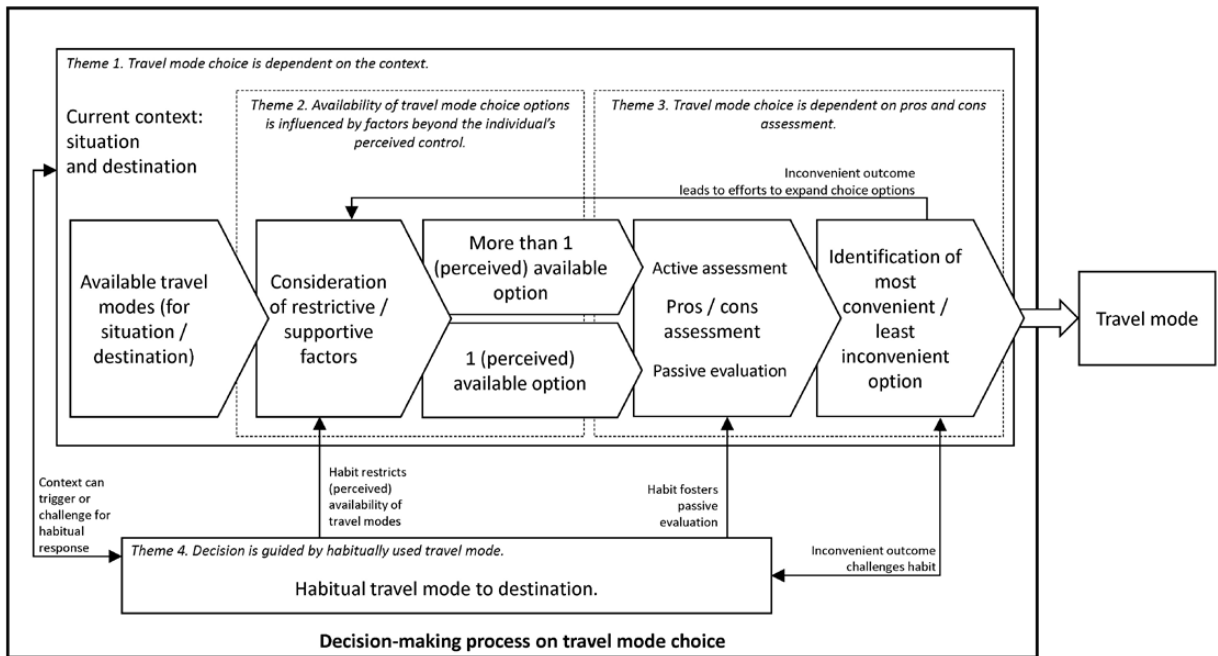
Fig. 1: Decision-making process according to adolescents.

school, about a five minute drive I think, so that fits perfectly, she would also drive by when she goes to work.

Despite being aware of environmental disadvantages, she concludes that traveling by car is the most convenient option, which is why she asked her mother to drive her to school (interaction Themes 3 and 2, interaction Themes 3 and 4). Thus, by agreeing to her daughter's request, the mother enlarged travel mode options by enabling the travel mode 'car' (Theme 2).

DISCUSSION

The aim of this study was to gain a deeper understanding of the process of adolescents' decision-making on travel mode choice. Thematic analysis generated three themes (Themes 1, 2 and 3), which shaped the decision-making process, and one theme (Theme 4) that reoccurred throughout the process.

Adolescents made the decision on travel mode with regard to the travel context (Theme 1). Thus, there was no universal decision for one travel mode regardless of destination and situation. Considering previous findings from Germany indicating that youth aged 10–19 travel more ways for leisure purposes than to school (Nobis and Kuhnimhof, 2018), our findings emphasize the need for future research to consider multiple destinations of adolescents' daily living. Furthermore,

this implies that interventions to promote, for example, cycling to school, cannot be expected to influence cycling to other destinations. When considering destinations that were frequently traveled using specific travel modes, this travel mode appeared to be established as a habit (Theme 4). Habits describe automatically executed actions, which are triggered by the context associated with the respective behavior (Wood and Neal, 2007; Lally *et al.*, 2010). Given that a certain destination acted as such a trigger, the established travel mode was used even in unfavorable circumstances. Concerning the situational context, interventions might benefit from approaches that consider adolescents' daily schedules including, for example, leisure activities after school that demand certain travel modes. Additionally, creating situations that deviate from daily practices can potentially provoke adolescents to reconsider habitual travel mode choices.

Next in the decision-making process, adolescents experienced different factors (i.e. environmental, social and personal) that restricted or enlarged travel mode choice options (Theme 2). Previous research has demonstrated the influence of such factors on travel mode choice (Panter *et al.*, 2008; Larouche and Ghekiere, 2018). Theme 2 illustrates adolescents' processing of such factors during their decision-making. Adolescents perceived these factors and the respective influence on the availability of travel mode choice as beyond their control. Similarly, the research found that adolescents differed individually in their perception of

what factors and to what extent they restricted travel mode choices (Møller *et al.*, 2018). Although adolescents in our study varied individually in the extent of the perceived restrictions, improving these factors to create favorable (environmental and individual) conditions, might contribute to adolescents' perception of having multiple options rather than being restricted. This is particularly relevant, since the opportunity to freely choose what to do is inherent to the concept of autonomy (Deci and Ryan, 1987). Besides the fact that autonomy is essential for adolescents' development (Spear and Kulbok, 2004), experiencing limited freedom of choice and thus constraints on autonomy satisfaction, might also negatively impact adolescents' well-being (Deci and Ryan, 2000; Yu *et al.*, 2018).

Considering adolescents' control beliefs, built and social environmental, as well as individual factors were perceived as uncontrollable. Specifically, regarding the built environment this calls for policy actions to enable more healthy and sustainable options. On the individual level, adolescents perceived, for example, motivation or capability as externally controlled. This might have resulted from the habitual use of a certain travel mode (Theme 4). Since habitual actions are triggered by external cues, motivational processes and conscious attention are less required for action initiation (Lally *et al.*, 2011). This may have led to the personal factors being perceived as externally controlled. Therefore, behavioral interventions might benefit from appropriate behavior change techniques (Michie *et al.*, 2013; Gillison *et al.*, 2019) that address adolescents' personal factors (e.g. motivation, capability). This might increase perceived control leading to a reduction of unconscious barriers in habitual travel and an increase of available travel modes when traveling to less frequently visited destinations.

In the social environment, adolescents perceived an external locus of control and considered themselves unable to influence their friends' decisions. This might explain previous findings of the strong influence of friends on adolescents' travel behavior (Ducheyne *et al.*, 2012; Roberts *et al.*, 2019). Therefore, shifting adolescents' locus of control internally might not only increase (perceived) availability of travel mode options, but could additionally influence friends' choices. In our study, parents had a special role within the social factors. Many quantitative studies show that even in adolescence, parents still influence decision-making on travel mode (Aranda-Balboa *et al.*, 2019; Mandic *et al.*, 2020). This is consistent with our findings, especially when parents restricted adolescents to one travel mode. Along with this, adolescents primarily perceived parents as a potentially expanding option of travel modes, specifically for traveling by car (interaction of Theme 2 with Theme 3). In regard to health promotion, two

implications result from this finding. First, concerning adolescents, reinforcing the disadvantages of driving by car could shift the pros and cons assessment toward judging car use as disadvantageous. This might subsequently prevent adolescents' action taking to ask their parents to drive them. Second, parents need to be aware that they are the providers of this travel mode option. Thus, making this option not available to the adolescent, would restrict choice options to potentially more healthy or sustainable travel modes (e.g. waking, cycling, public transport). Additionally, targeting parents, who regularly drive their child, might help to shift adolescents' decision-making toward a conscious process. Convincing parents to stop providing the car could inhibit unreasoned habitual car use and requires conscious processing of alternatives. Therefore, in the sense of health promotion, increasing adolescents' travel mode options should be balanced between enabling adolescents' sense of autonomy (i.e. choosing freely) and focusing on active travel mode options. Overall, our findings provide first insights into how the construct of perceived behavioral control (Ajzen, 1991), which has previously been found to influence travel decisions (Murtagh *et al.*, 2012; Zaragoza *et al.*, 2020), is experienced during decision-making.

Finally, during decision-making, adolescents weighed the pros and cons of the (perceived) available travel modes to identify the most convenient option (Theme 3). Overall, this assessment provides good implications for promoting active travel, for example, through favorable attitudes or outcome expectations. Previous research has identified the potential benefit of increasing environmental awareness for travel mode choices in terms of adolescents' pros and cons assessment (Møller *et al.*, 2018). Establishing positive attitudes toward active travel, such as experiencing a travel mode as pleasurable, can at least increase the intention to use that travel mode (Stark and Hössinger, 2018). Still, travel mode priorities (i.e. what was evaluated as advantageous or disadvantageous) appeared to differ between individuals in our study. Previous research on university students has identified relationships between specific priorities (e.g. flexibility, exercise) and travel mode choice (Egset and Nordfjærn, 2019). Thus, future research should consider assessing such relationships in the adolescent population. However, previous research has highlighted that the value an individual ascribes to a travel mode and the resulting priority assessment is highly subjective and limited by the individuals' perception (Götschi *et al.*, 2017). In our study, adolescents predominantly favored convenient travel modes that involved the least stressful experience. This might be related to the increase in schoolwork pressure and decreasing mental well-being among adolescents in Germany (Cosma *et al.*, 2020). Since physical

activity can sufficiently contribute to reducing adolescents' mental load (Kudláček *et al.*, 2016), raising adolescents' awareness of this compensatory potential can contribute to a more positive assessment of active travel modes. Additionally, it is important to note that especially in habitual travel, such assessment might not be consciously processed to a large extent (Lally *et al.*, 2011) and habits might persist even when the evaluation of travel modes has been altered (Gardner *et al.*, 2011). Since habit substitution can be achieved by directing attention to behavioral alternatives (Gardner *et al.*, 2020), the pros and cons assessment could still provide a good starting point for interventions. In such instances, promoting the convenience and advantages of active travel might increase the likelihood of consciously processing them during the assessment process leading to prioritizing active travel modes.

Lastly, adolescents did not decide to 'travel actively' or to 'travel passively'. Sometimes, during the weighing of pros and cons, adolescents considered physical activity as a concomitant of a travel mode, but during the decision-making process, all travel modes were considered individually. Against the background of the conceptual discussion of the term 'active travel' (Cook *et al.*, 2022), adolescents' focus on individual travel modes appears logical. Future studies should consider this, especially when designing interview guides or questionnaires, by referring to individual travel modes. This is also suggested by recent quantitative research (Mandic *et al.*, 2022).

Summarizing, the interviews revealed that for most destinations adolescents had already established a habitual behavior of using a specific travel mode. In those cases, choosing a travel mode was rather an automatic contextual response than a conscious process. However, sometimes adolescents report deviations from habitual choices. Conscious decision-making was enabled when the usual travel mode was judged more inconvenient compared to other travel modes or the context changed. Such disruptions of the contextual triggers of a habitual response have previously been found to enable conscious processing of information (Wood *et al.*, 2005; Verplanken *et al.*, 2008).

The study has several strengths worth mentioning. We focused on the population of adolescents and included several destinations of daily living. The flexibility of the semi-structured interviews allowed participants to express topics that were not included in the interview guide. Yet, the interview guide facilitated to discuss all topics of interest. Online interviews were conducted to ensure that participants would not be exposed to any unnecessary health risks during the Covid-19 pandemic. In an adult population, online interviews were found to be an acceptable and appropriate tool (Gray *et al.*, 2020). Additionally, the online interviews might have benefited from the somewhat more face-to-face experience compared to telephone interviews, and the resulting improved interpretation of nonverbal cues (Novick, 2008). The thematic analysis demonstrates a suitable method in health research to capture participants' experiences of a certain topic (Braun and Clarke, 2006, 2014). The combination of deductive and inductive coding allowed a largely data-driven analysis process without neglecting theoretical considerations. Furthermore, analysis and conclusions drawn from the data were repeatedly discussed and negotiated within the research team.

However, the study has some limitations that need to be mentioned. Despite the strength of the online interviews, bad internet connection sometimes disrupted the narrative flow. Potential recall bias and socially desirable responses should be considered. Furthermore, thematic analysis is limited in its ability to uncover discrepancies across the interviews as statements are aggregated into consistent opinions (Braun and Clarke, 2006). In light of this opinion formation, the small number of interviews represents a potential influence on the results. Lastly, it is important to acknowledge the researcher's active participation in identifying and selecting themes, and in reporting (Braun and Clarke, 2006).

CONCLUSION

In our study, adolescents experience the decision-making process on travel mode choice as highly contextual dependent (destination and situation). In the case of frequently traveled destinations, this results in unreasoned action-taking, where conscious processes are largely missed and a destination serves as a trigger for a habitual travel mode choice. This indicates the need for interventions to other destinations than school to consider situational circumstances. Next, adolescents consider the availability of travel modes, which they experienced as influenced by various factors (i.e. built environment, social and individual) beyond their control. In habitual travel, adolescents' perception is restricted to one available travel mode (i.e. the one that is usually used to the respective destination). Interventions should be balanced between increasing adolescents' sense of control and thus the (perceived) availability of travel mode options and promoting the advantages of active travel modes. Such advantages are processed in the last step during adolescents' decision-making to identify the most convenient option. However, interventions should consider that the decision to use an 'active travel mode' is only partially based on the advantage of increased physical activity and limited by adolescents' preferences. Thus, interventions should

be specific to individual travel modes and focus on a variety of benefits associated with them. Since the assessment process is largely missed in habitual travel resulting in a passive judgment of the usually used travel mode, future interventions should incorporate components that lead to the conscious processing of health-enhancing alternatives during decision-making. Particularly, parents could help shift adolescents' unreasoned decision-making toward conscious processing of alternatives by precluding certain travel modes that might be detrimental to health.

SUPPLEMENTARY MATERIAL

Supplementary material is available at *Health Promotion International* online.

AUTHORS' CONTRIBUTIONS

Conceptualization: D.R., Y.D.; Methodology: D.R., Y.D., I.M., C.K.; Investigation: D.R., I.M.; Formal analysis: D.R.; Writing—original draft: D.R.; Writing—review and editing: D.R., A.K.R., I.M., F.B., C.K., Y.D.; Visualization: D.R.; Supervision: Y.D.

ETHICAL APPROVAL

The ARRIVE study received ethical approval from the ethics commission of the Friedrich-Alexander-Universität Erlangen-Nürnberg, Germany (Reg. 249_21 B).

DATA AVAILABILITY

Data will be made available upon reasonable request.

CONFLICT OF INTEREST STATEMENT

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

REFERENCES

Ajzen, I. (1991) The theory of planned behavior. *Organizational Behavior and Human Decision Processes*, **50**, 179–211.

Alfonzo, M. A. (2005) To walk or not to walk? The hierarchy of walking needs. *Environment and Behavior*, **37**, 808–836.

Andersen, L. B., Wedderkopp, N., Kristensen, P., Moller, N. C., Froberg, K. and Cooper, A. R. (2011) Cycling to school and cardiovascular risk factors: a longitudinal study. *Journal of Physical Activity and Health*, **8**, 1025–1033.

Aranda-Balboa, M. J., Huertas-Delgado, F. J., Herrador-Colmenero, M., Cardon, G. and Chillon, P. (2019) Parental barriers to active transport to school: a systematic review. *International Journal of Public Health*, **65**, 87–98.

Blakemore, S. -J. and Robbins, T. W. (2012) Decision-making in the adolescent brain. *Nature Neuroscience*, **15**, 1184–1191.

Braun, V. and Clarke, V. (2006) Using thematic analysis in psychology. *Qualitative Research in Psychology*, **3**, 77–101. https://doi.org/10.1191/1478088706qp063oa

Braun, V. and Clarke, V. (2014) What can 'thematic analysis' offer health and wellbeing researchers? *International Journal of Qualitative Studies on Health and Well-being*, **9**, 26152.

Braun, V., Clarke, V., and Weate, P. (2016). Using thematic analysis in sport and exercise research. In Smith, B. and Sparkes, A. C. (eds), *Routledge Handbook of Qualitative Research in Sport and Exercise*. Routledge, London, pp. 213–227.

Burbidge, S. and Goulias, K. (2009) Active travel behavior. *Transportation Letters*, **1**, 147–167.

Burgueño, R., González-Cutre, D., Sevil-Serrano, J., Herrador-Colmenero, M., Segura-Díaz, J. M., Medina-Casaubón, J. *et al.* (2019) Understanding the motivational processes involved in adolescents' active commuting behaviour: development and validation of the Behavioural Regulation in Active Commuting to and from School (BR-ACS) Questionnaire. *Transportation Research Part F: Traffic Psychology and Behaviour*, **62**, 615–625.

Burgueño, R., González-Cutre, D., Sevil-Serrano, J., Herrador-Colmenero, M., Segura-Díaz, J. M., Medina-Casaubón, J. *et al.* (2020) Validation of the Basic Psychological Need Satisfaction in Active Commuting to and from School (BPNS-ACS) Scale in Spanish young people. *Journal of Transport & Health*, **16**, 100825.

Buttazzoni, A., Nelson Ferguson, K. and Gilliland, J. (2023) Barriers to and facilitators of active travel from the youth perspective: a qualitative meta-synthesis. *SSM Popul Health*, **22**, 101369.

Chillón, P., Hales, D., Vaughn, A., Gizlice, Z., Ni, A. and Ward, D. S. (2014) A cross-sectional study of demographic, environmental and parental barriers to active school travel among children in the United States. *The International Journal of Behavioral Nutrition and Physical Activity*, **11**, 61.

Chillón, P., Ortega, F. B., Ruiz, J. R., Veidebaum, T., Oja, L., Mäestu, J. *et al.* (2010) Active commuting to school in children and adolescents: an opportunity to increase physical activity and fitness. *Scandinavian Journal of Public Health*, **38**, 873–879.

Clifton, K. J., and Handy, S. L. (2003) Qualitative methods in travel behaviour research. In Jones, P. and Stopher, P. R. (eds), *Transport Survey Quality and Innovation*. Emerald Group Publishing Limited, Bingley, pp. 283–302.

Cook, S., Stevenson, L., Aldred, R., Kendall, M. and Cohen, T. (2022) More than walking and cycling: what is 'active travel?'. *Transport Policy*, **126**, 151–161.

Cosma, A., Stevens, G., Martin, G., Duinhof, E. L., Walsh, S. D., Garcia-Moya, I. *et al.* (2020) Cross-national time trends in adolescent mental well-being from 2002 to 2018 and the explanatory role of schoolwork pressure. *Journal of Adolescent Health*, **66**, S50–S58.

Deci, E. L. and Ryan, R. M. (1987) The support of autonomy and the control of behavior. *Journal of Personality and Social Psychology*, **53**, 1024–1037.

Deci, E. L. and Ryan, R. M. (2000) The 'what' and 'why' of goal pursuits: human needs and the self-determination of behavior. *Psychological Inquiry*, **11**, 227–268.

Dresing, T. and Pehl, T. (2018) *Praxisbuch Interview, Transkription & Analyse. Anleitungen und Regelsysteme für qualitativ Forschende* (Vol. **8**). Marburg.

Ducheyne, F., De Bourdeaudhuij, I., Spittaels, H. and Cardon, G. (2012) Individual, social and physical environmental correlates of 'never' and 'always' cycling to school among 10 to 12 year old children living within a 30 km distance from school. *International Journal of Behavioral Nutrition and Physical Activity*, **9**, 142.

Egset, K. S. and Nordfjærn, T. (2019) The role of transport priorities, transport attitudes and situational factors for sustainable transport mode use in wintertime. *Transportation Research Part F: Traffic Psychology and Behaviour*, **62**, 473–482.

Esteban-Cornejo, I., Carlson, J. A., Conway, T. L., Cain, K. L., Saelens, B. E., Frank, L. D. *et al.* (2016) Parental and adolescent perceptions of neighborhood safety related to adolescents' physical activity in their neighborhood. *Research Quarterly for Exercise and Sport*, **87**, 191–199.

Faulkner, G. E. J., Richichi, V., Buliung, R. N., Fusco, C. and Moola, F. (2010) What's 'quickest and easiest?': parental decision making about school trip mode. *International Journal of Behavioral Nutrition and Physical Activity*, **7**, 62.

Forsberg, H., Rutberg, S., Mikaelsson, K. and Lindqvist, A. -K. (2020) It's about being the good parent: exploring attitudes and beliefs towards active school transportation. *International Journal of Circumpolar Health*, **79**, 1798113.

Gardner, B., de Bruijn, G. -J. and Lally, P. (2011) A systematic review and meta-analysis of applications of the self-report habit index to nutrition and physical activity behaviours. *Annals of Behavioral Medicine*, **42**, 174–187.

Gardner, B., Rebar, A. L., and Lally, P. (2020) Habit Interventions. In Hamilton, K., Cameron, L. D., Hagger, M. S., Hankonen, N. and Lintunen, T. (eds), *The Handbook of Behavior Change*. Cambridge University Press, Cambridge, pp. 599–616.

Gillison, F. B., Rouse, P., Standage, M., Sebire, S. J. and Ryan, R. M. (2019) A meta-analysis of techniques to promote motivation for health behaviour change from a self-determination theory perspective. *Health Psychology Review*, **13**, 110–130.

Götschi, T., de Nazelle, A., Brand, C. and Gerike, R.; PASTA Consortium. (2017) Towards a comprehensive conceptual framework of active travel behavior: a review and synthesis of published frameworks. *Current Environmental Health Reports*, **4**, 286–295.

Gray, L. M., Wong-Wylie, G., Rempel, G. R. and Cook, K. (2020) Expanding qualitative research interviewing strategies: zoom video communications. *The Qualitative Report*, **25**, 1292–1301.

Hasanzadeh, K., Ikeda, E., Mavoa, S. and Smith, M. (2022) Children's physical activity and active travel: a cross-sectional study of activity spaces, sociodemographic and neighborhood associations. *Children's Geographies*, **21**, 287–305.

Henriques-Neto, D., Peralta, M., Garradas, S., Pelegrini, A., Pinto, A. A., Sánchez-Miguel, P. A. *et al.* (2020) Active commuting and physical fitness: a systematic review. *International Journal of Environmental Research and Public Health*, **17**, 2721.

Ikeda, E., Hinckson, E., Witten, K. and Smith, M. (2018) Associations of children's active school travel with perceptions of the physical environment and characteristics of the social environment: a systematic review. *Health & Place*, **54**, 118–131.

Kleszczewska, D., Mazur, J., Bucksch, J., Dzielska, A., Brindley, C. and Michalska, A. (2020) Active transport to school may reduce psychosomatic symptoms in school-aged children: data from nine countries. *International Journal of Environmental Research and Public Health*, **17**, 8709.

Kudláček, M., Frömel, K., Jakubec, L. and Groffik, D. (2016) Compensation for adolescents' school mental load by physical activity on weekend days. *International Journal of Environmental Research and Public Health*, **13**, 308.

Lally, P., van Jaarsveld, C. H. M., Potts, H. W. W. and Wardle, J. (2010) How are habits formed: modelling habit formation in the real world. *European Journal of Social Psychology*, **40**, 998–1009.

Lally, P., Wardle, J. and Gardner, B. (2011) Experiences of habit formation: a qualitative study. *Psychology, Health & Medicine*, **16**, 484–489.

Larouche, R. and Ghekiere, A. (2018). An ecological model of active transportation. In Larouche, R. (ed.), *Children's Active Transportation*. Elsevier, Amsterdam, pp. 93–103.

Larouche, R., Saunders, T. J., Faulkner, G. E. J., Colley, R. and Tremblay, M. (2014) Associations between active school transport and physical activity, body composition, and cardiovascular fitness: a systematic review of 68 studies. *Journal of Physical Activity and Health*, **11**, 206–227.

Levi, S. and Baron-Epel, O. (2022) 'It's a kind of freedom': adolescents and parents speak about motivations for active travel and COVID-19. *International Journal of Qualitative Studies on Health and Well-being*, **17**, 2130508.

Mandic, S., García Bengoechea, E., Hopkins, D., Coppell, K. and Spence, J. C. (2022) Adolescents' perceptions of walking and cycling to school differ based on how far they live from school. *Journal of Transport & Health*, **24**, 101316.

Mandic, S., Hopkins, D., García Bengoechea, E., Flaherty, C., Coppell, K., Moore, A. *et al.* (2020) Differences in parental perceptions of walking and cycling to high school according to distance. *Transportation Research Part F: Traffic Psychology and Behaviour*, **71**, 238–249.

Mandic, S., Leon de la Barra, S., Garcia Bengoechea, E., Stevens, E., Flaherty, C., Moore, A. *et al.* (2015) Personal, social and environmental correlates of active transport to

school among adolescents in Otago, New Zealand. *Journal of Science and Medicine in Sport*, 18, 432–437.

Michie, S., Richardson, M., Johnston, M., Abraham, C., Francis, J., Hardeman, W. *et al.* (2013) The behavior change technique taxonomy (v1) of 93 hierarchically clustered techniques: building an international consensus for the reporting of behavior change interventions. *Annals of Behavioral Medicine*, 46, 81–95.

Mikkelsen, B., Williams, J., Rakovac, I., Wickramasinghe, K., Hennis, A., Shin, H.-R. *et al.* (2019) Life course approach to prevention and control of non-communicable diseases. *BMJ*, 364, l257.

Mindell, J. S., Ergler, C., Hopkins, D. and Mandic, S. (2021) Taking the bus? Barriers and facilitators for adolescent use of public buses to school. *Travel Behaviour and Society*, 22, 48–58.

Mitra, R. (2013) Independent mobility and mode choice for school transportation: a review and framework for future research. *Transport Reviews*, 33, 21–43.

Møller, M., Haustein, S. and Bohlbro, M. S. (2018) Adolescents' associations between travel behaviour and environmental impact: a qualitative study based on the Norm-Activation Model. *Travel Behaviour and Society*, 11, 69–77.

Moran, M., Plaut, P. and Baron-Epel, O. (2016) Do children walk where they bike? Exploring built environment correlates of children's walking and bicycling. *Journal of Transport and Land Use*, 9, 43–65.

Murtagh, S., Rowe, D. A., Elliott, M. A., McMinn, D. and Nelson, N. M. (2012) Predicting active school travel: the role of planned behavior and habit strength. *The International Journal of Behavioral Nutrition and Physical Activity*, 9, 65.

Nagl-Cupal, M. (2013) Theoretical sampling. *ProCare*, 18, 20–22.

Nelson, N. M., Foley, E., O'Gorman, D. J., Moyna, N. M. and Woods, C. B. (2008) Active commuting to school: how far is too far? *The International Journal of Behavioral Nutrition and Physical Activity*, 5, 1.

Nobis, C. and Kuhnimhof, T. (2018) *Mobilität in Deutschland— MiD Ergebnisbericht. Studie von infas, DLR, IVT und infas 360 im Auftrag des Bundesministers für Verkehr und digitale Infrastruktur (FE-Nr. 70.904/15)*. www.mobilitaet-in-deutschland.de

Novick, G. (2008) Is there a bias against telephone interviews in qualitative research? *Research in Nursing & Health*, 31, 391–398.

Panter, J. R., Jones, A. P. and van Sluijs, E. M. (2008) Environmental determinants of active travel in youth: a review and framework for future research. *The International Journal of Behavioral Nutrition and Physical Activity*, 5, 34.

Panter, J. R., Jones, A. P., van Sluijs, E. M. F. and Griffin, S. J. (2010) Attitudes, social support and environmental perceptions as predictors of active commuting behaviour in school children. *Journal of Epidemiology and Community Health*, 64, 41–48.

Pont, K., Ziviani, J., Wadley, D. and Abbott, R. (2011) The Model of Children's Active Travel (M-CAT): a conceptual framework for examining factors influencing children's active travel. *Australian Occupational Therapy Journal*, 58, 138–144.

Pont, K., Ziviani, J., Wadley, D., Bennett, S. and Abbott, R. (2009) Environmental correlates of children's active transportation: a systematic literature review. *Health & Place*, 15, 849–862.

Reimers, A. K., Marzi, I., Beck, F., Engels, E., Renninger, D., Buttazzoni, A. *et al.* (2022) Active travel behaviour in the family environment: protocol for the mixed-methods cross-sectional ARRIVE study. *BMJ Open*, 12, e056383.

Reimers, A. K., Marzi, I., Schmidt, S. C. E., Niessner, C., Oriwol, D., Worth, A. *et al.* (2020) Trends in active commuting to school from 2003 to 2017 among children and adolescents from Germany: the MoMo Study. *European Journal of Public Health*, 31, 373–378.

Roberts, J. D., Mandic, S., Fryer, C. S., Brachman, M. L. and Ray, R. (2019) Between privilege and oppression: an intersectional analysis of active transportation experiences among Washington DC area youth. *International Journal of Environmental Research and Public Health*, 16, 1313.

Simons, D., Clarys, P., De Bourdeaudhuij, I., de Geus, B., Vandelanotte, C. and Deforche, B. (2013) Factors influencing mode of transport in older adolescents: a qualitative study. *BMC Public Health*, 13, 323.

Smith, M., Hosking, J., Woodward, A., Witten, K., MacMillan, A., Field, A. *et al.* (2017) Systematic literature review of built environment effects on physical activity and active transport—an update and new findings on health equity. *International Journal of Behavioral Nutrition and Physical Activity*, 14, 158.

Spear, H. J. and Kulbok, P. (2004) Autonomy and adolescence: a concept analysis. *Public Health Nursing*, 21, 144–152.

Stark, J. and Hössinger, R. (2018) Attitudes and mode choice: measurement and evaluation of interrelation. *Transportation Research Procedia*, 32, 501–512.

Stark, J., Meschik, M., Singleton, P. A. and Schützhofer, B. (2018) Active school travel, attitudes and psychological well-being of children. *Transportation Research Part F: Traffic Psychology and Behaviour*, 56, 453–465.

Sweeney, S. M. and Von Hagen, L. A. (2016) Stranger danger, cell phones, traffic, and active travel to and from schools: perceptions of parents and children. *Transportation Research Record*, 2582, 1–7.

Tong, A., Sainsbury, P. and Craig, J. (2007) Consolidated criteria for reporting qualitative research (COREQ): a 32-item checklist for interviews and focus groups. *International Journal for Quality in Health Care*, 19, 349–357.

Trapp, G. S. A., Giles-Corti, B., Christian, H. E., Bulsara, M., Timperio, A. F., McCormack, G. R. *et al.* (2011) On your bike! a cross-sectional study of the individual, social and environmental correlates of cycling to school. *International Journal of Behavioral Nutrition and Physical Activity*, 8, 123.

Verhoeven, H., Simons, D., Van Dyck, D., Van Cauwenberg, J., Clarys, P., De Bourdeaudhuij, I. *et al.* (2016) Psychosocial and environmental correlates of walking, cycling, public transport and passive transport to various destinations in Flemish older adolescents. *PLoS One*, 11, e0147128.

Verplanken, B., Walker, I., Davis, A. and Jurasek, M. (2008) Context change and travel mode choice: combining the habit discontinuity and self-activation hypotheses. *Journal of Environmental Psychology*, 28, 121–127.

Wang, X., Conway, T. L., Cain, K. L., Frank, L. D., Saelens, B. E., Geremia, C. *et al*. (2017) Interactions of psychosocial factors with built environments in explaining adolescents' active transportation. *Preventive Medicine*, **100**, 76–83.

Westman, J., Friman, M. and Olsson, L. E. (2017) What drives them to drive?—Parents' reasons for choosing the car to take their children to school. *Frontiers in Psychology*, **8**, 1970.

White, R. L., Olson, R., Parker, P. D., Astell-Burt, T. and Lonsdale, C. (2018) A qualitative investigation of the perceived influence of adolescents' motivation on relationships between domain-specific physical activity and positive and negative affect. *Mental Health and Physical Activity*, **14**, 113–120.

WHO. (2018) *Global Action Plan on Physical Activity 2018–2030: More Active People for a Healthier World*. World Health Organization, Geneva.

Wilson, K., Clark, A. F. and Gilliland, J. A. (2018) Understanding child and parent perceptions of barriers influencing children's active school travel. *BMC Public Health*, **18**, 1053.

Wood, W. and Neal, D. T. (2007) A new look at habits and the habit-goal interface. *Psychological Review*, **114**, 843–863.

Wood, W., Tam, L. and Witt, M. G. (2005) Changing circumstances, disrupting habits. *Journal of Personality and Social Psychology*, **88**, 918–933.

Yu, S., Levesque-Bristol, C. and Maeda, Y. (2018) General need for autonomy and subjective well-being: a meta-analysis of studies in the US and East Asia. *Journal of Happiness Studies*, **19**, 1863–1882.

Zaragoza, J., Corral, A., Ikeda, E., García-Bengoechea, E. and Aibar, A. (2020) Assessment of psychological, social cognitive and perceived environmental influences on children's active transport to school. *Journal of Transport & Health*, **16**, 100839.

4 Discussion

Promoting active travel offers a powerful solution to global challenges, including combating health consequences from physical inactivity, mitigating climate change through sustainable transportation, and promoting equality by providing all adolescents with an accessible opportunity for physical activity. To guide evidence-based interventions and policies, a comprehensive understanding of the factors underlying active travel behavior is needed. This thesis addressed motivation as a determinant of active travel in adolescents' decision-making process regarding travel mode choice. It provides a validation of the first German questionnaire to assess behavioral regulation in general active travel in adolescent boys and girls. Further, this dissertation explored sex/gender differences in behavioral regulations and their varying relationship with active travel behavior among boys and girls. Using a person-centered approach, the dissertation identifies clusters of adolescents with similar motivational characteristics, including intrinsic motivation, integrated regulation, identified regulation, introjected regulation, external regulation, amotivation, as well as the satisfaction of the three basic psychological needs autonomy, competence, and relatedness. Lastly, the conceptualization of the decision-making process on travel mode choice enhances the knowledge on how adolescents process motivation during decision-making.

4.1 Assessing motivation for general active travel

4.1.1 German questionnaire to assess behavioral regulations in general active travel

The results of the CFA indicate that the translated and adapted questionnaire is a valid tool to assess motivation for general active travel in adolescent boys and girls. However, as outlined in the decision-making process on travel mode choice (Renninger, Reimers, et al., 2023), choosing an active travel mode highly depended on the specific destination an adolescent aimed to reach. This aligns with quantitative results indicating that using an active travel mode varies across destinations (Renninger, Bachner, et al., 2023, Supplement 1), as illustrated by Figure 3.

Figure 3. *Percentage of adolescents included in the ARRIVE study traveling actively to school, home from school, to friends or relatives, to shopping facilities, or to leisure facilities (Renninger, Bachner, et al., 2023).*
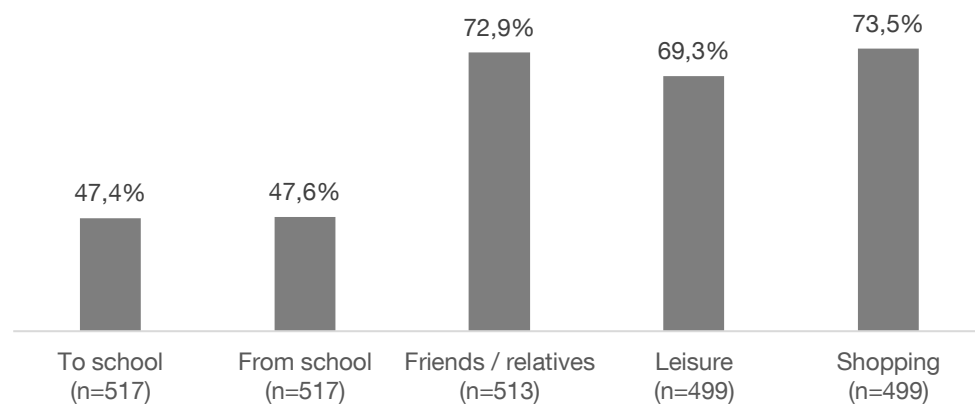
This questions whether assessing motivation toward general active travel is appropriate to explain active travel behavior to specific destinations. For this purpose, findings from the cluster analysis can be considered (Renninger, Bachner, et al., 2023). The identified clusters, based on motivation for general active travel, were significantly associated with choosing an active travel mode to and from school, to friends or relatives, to leisure facilities, and to shopping facilities. For instance, in C6 and C5 more adolescents traveled to school actively, while more adolescents traveled passively in C1 (Supplement 1, Renninger, Bachner, et al., 2023). Therefore, although not destination-specific, motivational profiles were relevant in explaining active travel behavior to specific destinations.

To explain this, the Hierarchical Model of Intrinsic and Extrinsic Motivation (Vallerand, 1997, 2007) can be utilized (see Figure 4). The model proposes that intrinsic motivation, extrinsic motivation, and amotivation operate at three levels of generality: on a situational (or state), contextual (or life domain), and global level (or personality). The global level describes an individual's general (or global) motivational orientation. At the contextual level, motivation refers to an individual's motivation in a specific life context, such as education, work, or exercise. Situational motivation addresses an individual's motivation to engage in a particular activity at a specific time. Thus, motivation for general active travel, as assessed in this dissertation, can be understood as contextual motivation.

Figure 4. *The hierarchical model of intrinsic and extrinsic motivation adapted from Vallerand (2007) to illustrate how multiple contextual motivations might influence travel behavior.*
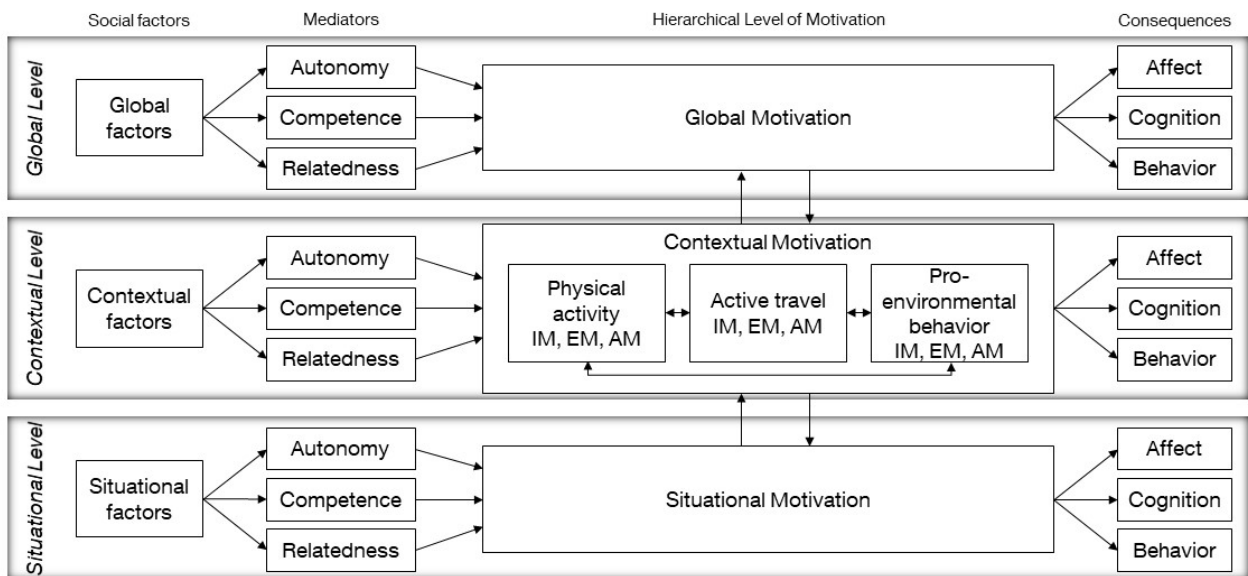
Note: IM = intrinsic motivation, EM = extrinsic motivation, AM = Amotivation; Motivation for physical activity and pro-environmental behavior are examples of further contextual motivation in this figure based on the various benefits of active travel.

The model proposes bottom-up (situational motivation → contextual motivation → general motivation) as well as top-down (general motivation → contextual motivation → situational motivation) effects between the levels of generality (Vallerand, 2007). This helps explain why motivation for general active travel (i.e., non-destination-specific) helps to understand destination-specific active travel behavior.

4.1.2 Methodological considerations from variable-centered and person-centered approaches

To enhance the understanding of motivation as a determinant of active travel, two studies examined associations of behavioral regulations with active travel behavior, using two different statistical approaches (variable-centered and person-centered). While the variable-centered approach (Renninger et al., 2022) assessed the strength and direction of the relationship between behavioral regulations and active travel behavior, the person-centered approach (Renninger, Bachner, et al., 2023) identified clusters of adolescents that share similar motivational characteristics.

Findings concerning sex/gender illustrate the differences in approaching motivation via a variable- or person-centered approach. When running regression analyses separately for boys and girls, sex/gender differences emerged in the behavioral regulation-travel behavior relationship, suggesting that girls would benefit most from external and integrated regulation,

while identified regulation provided the most advantages for boys (Renninger et al., 2022). When assessing motivational profiles, we could not find an association with sex/gender, suggesting these profiles appear equally in boys and girls (Renninger, Bachner, et al., 2023). Thus, equally for boys and girls, a profile of high autonomous motivation with low controlled motivation and low amotivation appears most advantageous regarding active travel, and a profile of high controlled motivation and amotivation with low autonomous motivation appears most disadvantageous. However, it is noteworthy that although the association of sex/gender and cluster has not reached statistical significance, a descriptive difference is observable (see Figure 5).

Figure 5. *Boys and girls in the six clusters (Renninger, Bachner, et al., 2023).*
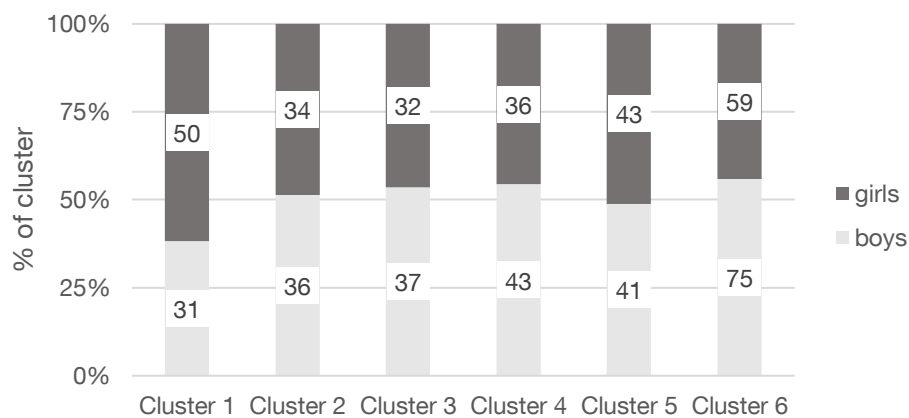
Note: Numbers within the bars represent the absolute number of boys or girls in the respective cluster

Despite these differences, using both a variable- and person-centered approach, the findings from the two studies can complement each other, helping to better understand motivation in the context of active travel.

Both approaches uniformly recognize that amotivation demonstrates a barrier toward general active travel. The person-centered approach (Renninger, Bachner, et al., 2023) illustrates that clusters with low quantity of motivation (low levels of autonomous and controlled types of motivation) and corresponding high amotivation included adolescents with the lowest active travel behavior. Similarly, the variable-based approach (Renninger et al., 2022) identified a significant negative association between amotivation with active travel. Further, the role of intrinsic motivation becomes more apparent when results from both studies are considered simultaneously. The variable-based approach (Renninger et al., 2022) found no association of intrinsic motivation with active travel behavior, suggesting that this type of motivation is not relevant in promoting active travel behavior among adolescents. However, the inspection of the profiles produced by the cluster analysis (Renninger, Bachner, et al., 2023) reveals that

the clusters with the highest active travel behavior featured highest intrinsic motivation. These findings indeed point to the relevance of intrinsic motivation. Considering both findings together, they indicate that intrinsic motivation may either demonstrate a prerequisite upon which additional behavioral regulations can operate to make decisions, or a concomitant stemming from the perceived enjoyment while traveling actively, even though other motivational types were responsible for choosing an active travel mode. Following this, the person-oriented approach (Renninger, Bachner, et al., 2023) discloses that while controlled types of motivation are essential to create a profile that is high in motivation quantity, high levels of autonomous types of motivation within the same cluster remain crucial in terms of creating an advantageous profile for active travel. In contrast, the variable-based approach (Renninger et al., 2022) highlights the significant role of for instance extrinsic regulation, particularly for girls, regardless of autonomous types of motivation.

4.2 Motivation during decision-making on travel mode choice

In SDT, it is assumed that individuals who are autonomously motivated, particularly highly intrinsically motivated, are more likely to perform and maintain behavior compared to those with lower-quality motivation (Deci & Ryan, 2000; Ryan & Deci, 2000). Thus, autonomous types of motivation, particularly intrinsic motivation, were expected to express a strong association with higher active travel behavior in adolescents, while controlled types of motivation would express none or negative associations. However, as previously described, findings from the quantitative studies only partially align with these assumptions (Renninger, Bachner, et al., 2023; Renninger et al., 2022). Using the findings from the qualitative study (Renninger, Reimers, et al., 2023) helps to delve deeper into the complexities of motivation during decision-making on travel mode choice.

4.2.1 Navigating the interplay of controlled and autonomous motivation to reduce amotivation

Findings from the two quantitative studies emphasize the detrimental impact of amotivation on active travel behavior (Renninger, Bachner, et al., 2023; Renninger et al., 2022). Additionally, the conceptualization outlining the decision-making process on travel mode choice suggests that lacking motivation involves perceiving fewer travel mode options to choose from (Renninger, Reimers, et al., 2023). In other words, a lack of motivation excludes the respective travel mode from those options that an adolescent perceives as available to choose. Therefore, it initially seems necessary that motivation is present, regardless of whether it is controlled or autonomous. This assumption can also be inferred from the quantitative findings. The regression analysis suggests a particular benefit from external regulation for girls (controlled type of motivation), as well as benefits from autonomous types

of motivation for boys and girls (Renninger et al., 2022). Findings from cluster analysis suggest that a profile high in motivation quantity is more beneficial in terms of active travel behavior compared to a profile with low motivation quantity. There was no statistically significant difference in active travel behavior between a profile with mainly high levels of autonomous types of motivation (C6 and C4) compared to a profile with high levels of controlled types in addition to high levels of autonomous types of motivation (C5) (Renninger, Bachner, et al., 2023).

Considering the qualitative findings (Renninger, Reimers, et al., 2023), it becomes more apparent when fostering autonomous types of motivation might be more beneficial and when promoting controlled types of motivation is worthwhile.

Indications that *autonomous types of motivation* could be more favorable than controlled types are disclosed in the final stage of decision-making, where adolescents intentionally evaluate the pros and cons of various travel modes to determine the most convenient option that minimizes stress (Theme 3; Renninger, Reimers, et al., 2023). To illustrate, motivation might interact with the general attitude toward a travel mode: consciously valuing active travel modes because of the provided health or environmental benefits (relating to identified regulation) or expecting fun while traveling actively (relating to intrinsic motivation) might prompt a decision favoring an active travel mode. Such associations between motivation and attitude have been addressed in previous research that integrates SDT and the Theory of Planned Behavior (TPB) (Hagger & Chatzisarantis, 2007, 2009). The proposed Integrated Behavior Change Model for physical activity (Hagger & Chatzisarantis, 2014) posits a direct relationship between motivation and TPB's constructs (attitude, subjective norm, and perceived behavioral control), as well as an indirect impact of motivation on behavioral intention through these constructs (see Figure 6).

Findings suggest that autonomous motivation was significantly related to attitudes and perceived behavioral control and showed a significant indirect effect on behavioral intentions through these constructs (Hagger & Chatzisarantis, 2007, 2009). The postulate of a formative relationship between motivation and TPB's constructs (Hagger & Chatzisarantis, 2007) resonates with our conceptualization of the decision-making process, indicating that motivation has the potential to shape personal attitudes. Considering the non-significant association of intrinsic motivation with active travel in the first publication (Renninger et al., 2022), it would be interesting to assess whether attitudes toward active travel might mediate this influence.

Figure 6. *Integrated Behavior Change Model for physical activity (according to Hagger & Chatzisarantis, 2014).*
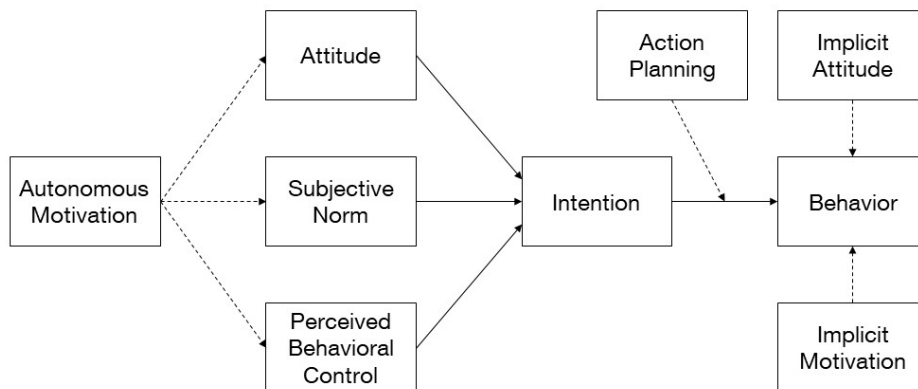
Note: Solid lines represent the pathways suggested by TPB, and dotted lines complement the TPB toward the Integrated Behavior Change Model.

Nevertheless, there are instances wherein *controlled types of motivation* are needed, for instance, when a decision on travel mode is habitually initiated (Gardner, 2015)[2]. Habits are likely to develop through frequent, successful participation in a behavior in specific contexts, leading to a shift from consciously and volitionally performing the behavior toward a more automatic, non-conscious performance (Gardner, 2015; Hagger, 2019). As the behavior becomes habituated, it is executed due to external environmental cues, while conscious motivation diminishes (Gardner, 2015). In the interviews, this was expressed, where habitually selecting a travel mode to a specific destination led to a passive evaluation of that travel mode rather than actively (i.e., consciously) engaging in decision-making (Renninger, Reimers, et al., 2023). Breaking existing habits to form new habits requires consciously engaging in alternative actions (Hagger, 2019). While autonomous forms of motivation are more likely to contribute to maintaining behavior and forming habits (Deci & Ryan, 2000; Hagger, 2019; Ryan & Deci, 2000), strong habits were found to fully mediate the significant effect of autonomous motivation on intention to switch from car to another travel mode (public transport, walking or cycling) (Rejeb, Bouscasse, Chalabaev, & Mathy, 2023). Therefore, external influences are required at the initial stage of behavior change (Gillison, Osborn, Standage, & Skevington, 2009; Vansteenkiste, Soenens, & Vandereycken, 2005). The resulting controlled types of motivation (external and introjected regulation) might assist in becoming familiar and competent in performing a new behavior (Gillison et al., 2009; Vansteenkiste et al., 2005), providing the base for internalizing motivation in the long-term. Subsequently, fostering *autonomous types of motivation* to regularly engage in a behavior

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[2] Habitual behavior can be distinguished between *habitually initiated behavior* and *habitually performed behavior* (Gardner, 2015).

can then help support habit formation (Hagger, 2019). Research in the domain of physical activity suggests that habits develop more quickly and stronger when the activities are based on autonomous motivation, and specifically intrinsic motivation (Gardner & Lally, 2013, 2018; Maltagliati et al., 2021). It is assumed that the interaction between past behavior and enjoyment of the activity reinforces the relationship between past performance and habit strength (Gardner & Lally, 2013).

When considering whether to promote autonomous or controlled types of motivation, it is crucial to reflect on the potential long-term costs associated with promoting controlled motivation, particularly concerning the maintenance of travel behavior and psychological wellbeing. Regarding travel behavior, individuals with autonomous motivation are more likely to maintain the behavior in the long-term (Deci & Ryan, 2000; Ryan & Deci, 2000). Research from physical activity settings supports this. Maintenance of leisure-time exercise in adolescents was positively predicted by autonomous motivation (Gillison, Standage, & Skevington, 2011). Intrinsic motivation significantly affected adolescents' maintenance of physical activity during the COVID-19 pandemic (Liu et al., 2023). While intrinsic motivation was found in adolescents who maintained high levels of physical activity throughout adolescence, a shift from intrinsic to extrinsic motivation was found in those adolescents whose physical activity levels had declined with age (Martins, Marques, Sarmento, & Carreiro da Costa, 2015). This questions whether adolescents from our research will sustain their active travel patterns despite their controlled motivations. Given the existing data on adolescents' travel behavior in Germany and the presented decline in active travel as age increases (Reimers et al., 2021), a plausible connection could be assumed.

Regarding psychological well-being, SDT suggests that behaviors resulting from autonomous motivation are associated with better psychological well-being than behaviors performed based on controlled motivation, which are likely to yield psychological costs (Deci & Ryan, 2008). In physical education and exercise, results from structural equation modeling revealed that autonomous motivation towards exercise positively predicted health-related quality of life in secondary school students (Standage, Gillison, Ntoumanis, & Treasure, 2012). Previous research on schoolchildren's travel to school has already found that although autonomous motivation was not associated with active travel behavior, it showed a positive association with affective well-being (White, Parker, et al., 2018). In a qualitative study, White, Olson, Parker, Astell-Burt, and Lonsdale (2018) concluded that individuals might only psychologically benefit from active travel when they are autonomously motivated and choose to walk or cycle, although alternatives would be possible.

4.2.2 Supporting internalization of motivation

The previous chapter illustrates that autonomous types of motivations, as well as controlled, types can result in active travel behavior, while amotivation should be reduced as much as possible. With this in mind, it is essential to consider that motivation, as an individual factor influencing the perceived availability of travel mode options (Theme 2; Renninger, Reimers, et al., 2023), is experienced by adolescents as beyond their control, thereby arising and disappearing without them being able to deliberately influence their motivation. Thus, when motivation, whether autonomous or controlled vanishes, this results in a state of lacking motivation that is amotivation. Consequently, considering SDT, internalization of motivation appears essential. During internalization, behavioral regulations are assimilated to someone's values and later transformed into their own (Ryan & Deci, 2000). Accordingly, highly internalized motivation relies less on external influences, which could lead to more consistent motivation and prevent adolescents from experiencing an abrupt lack of motivation. For instance, drawing from quotes from the third publication (Renninger, Reimers, et al., 2023), when an adolescent identifies as a "bicycle lover", this motivation (integrated regulation) for choosing an active travel mode might be more persistent than motivation based on the internal pressure to avoid "feeling bad somehow" (introjected regulation). This is specifically relevant considering that girls benefited significantly from external regulation, where external influences, such as social factors (e.g., parents), drive an individual's engagement in an activity (Renninger et al., 2022). Since controlled types of motivation tend to sustain behaviors only in the presence of the controlling contingencies (Hagger & Hamilton, 2021), with increasing age and maturation, this external influence might lose its effectiveness to create external regulation. This emphasizes the importance of internalizing motivation and addressing more types of motivation to compensate for a potential loss of relevance of one type of motivation.

To support the internalization of motivation to foster self-determined types of motivation, satisfying the three basic psychological needs of autonomy, competence, and relatedness is essential (Deci & Ryan, 2000; Ryan & Deci, 2000, 2017). Therefore, findings from cluster analysis can be considered (Renninger, Bachner, et al., 2023). Based on SDT, high levels of autonomy, competence, and relatedness satisfaction would correspond to high levels of autonomous types of motivation with low levels of controlled types of motivation and vice versa. Although findings demonstrated high levels of needs satisfaction across all clusters, significant differences could still be observed (Renninger, Bachner, et al., 2023). The findings align with SDT, emphasizing the importance of promoting autonomy, competence, and relatedness satisfaction in the domain of active travel to foster profiles including high levels

of autonomous types of motivation. While autonomy satisfaction was high in Cluster C5 (and comparable to C4), lower levels of relatedness and competence may have been responsible for the higher levels in controlled types of motivation. Such high levels of controlled types of motivation were not observed in Cluster C4 and C6, which expressed highest levels in relatedness and competence and higher levels of autonomy satisfaction, resulting in profiles featuring an autonomous distribution in the types of motivation. Further, considering that alongside autonomy satisfaction, active travel was highest and increased from C4 < C5 < C6, suggesting that providing autonomy plays a unique role in promoting active travel.

To enhance autonomy and, consequently, foster autonomous motivation, providing choice options is an important behavior-change technique (Gillison et al., 2019). Drawing on the conceptualization of the decision-making process, deliberately choosing a specific travel mode is only possible when adolescents perceive multiple options as available (Renninger, Reimers, et al., 2023). This is in line with Salvo, Jáuregui, Adlakha, Sarmiento, and Reis (2023), who illustrate that the presence of multiple feasible travel mode options demonstrates a precondition for autonomous choices. To increase the availability of feasible travel mode options, environmental, social, and personal factors need to be considered (Theme 2; Renninger, Reimers, et al., 2023). This could introduce tension between measures to promote active mobility and autonomous decision-making. Concerning the built environment, infrastructure and safety measures are crucial in providing travel mode choices. However, policies aiming at increasing costs, for example, for car users, thus making it unaffordable for families, might not be beneficial in supporting autonomous choices. In the social environment, friends' travel mode choices strongly influence adolescents' choices, thus potentially reducing perceived choice options. Likewise, parents sometimes prohibit specific travel modes or decide on behalf of their child. Although parent's decisions might be based on the intention to promote their child's active travel, this would result in a reduction in the number of travel modes from which the adolescent can choose, thus thwarting their child's autonomy. This emphasizes the importance of providing a supportive social environment (Gillison et al., 2019; Teixeira et al., 2020) to facilitate the satisfaction of autonomy, competence, and relatedness to foster autonomous motivation despite a potential reduction in the available travel mode options. Drawing on the previous example, when parents limit their child's travel mode options to active travel modes, they can still promote need satisfaction and autonomous motivation. This can be achieved, for instance, when parents "provide a rationale" (SDT 3[3], Gillison et al., 2019; MBCT[4] 5, Teixeira et al., 2020) for favoring active travel

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[3] SDT *X* = Number of strategy to promote need satisfaction identified by Gillison et al., 2019.
[4] MBCT = Motivation and Behavior Change Techniques classified by Teixeira et al., 2020

modes, "acknowledge the perspectives and feelings" (MBCT 8, Teixeira et al., 2020) of their child, or "provide support and encouragement" (SDT 15, Gillison et al., 2019) for traveling actively.

4.3 Future research directions

The findings from the three studies included in this thesis provide implications for developing interventions to promote active travel in adolescents through their motivation. One goal of such future intervention studies should be the reduction of amotivation, while providing support for autonomous types and controlled types of motivation depending on the prevailing circumstances. Hence, directing efforts to increase autonomous types of motivation, such as making active travel fun and enjoyable (intrinsic motivation), a part of adolescents' identity (integrated regulation), or meaningful (identified regulation), would be particularly effective to sustain active travel in adolescents. To achieve behavior change, interventions might initially benefit more from integrating aspects that introduce external incentives and pressures (external regulation) or internalized pressures (introjected regulation). Findings from Renninger, Reimers, et al. (2023) suggest including a sex/gender-sensitive development of such interventions.

However, to gain a more comprehensive understanding, the present research suggests a need for future research to incorporate additional variables when investigating motivation as a determinant of active travel. Relating to the Integrated Behavior Change Model for physical activity (Hagger & Chatzisarantis, 2014), research should consider including variables such as attitudes or perceived behavioral control to clarify the issue of the non-significant finding regarding intrinsic motivation for general active travel (Renninger et al., 2022). Further, given the disparities in the relationship between the autonomous behavioral regulations and active travel in boys and girls (Renninger et al., 2022), sex/gender-sensitive analyses when addressing the variables from Integrated Behavior Change Model (Hagger & Chatzisarantis, 2014), is highly recommended.

To enable conclusions about autonomous travel mode choices, the amount of available travel modes should be assessed with regard to the destination under investigation. This aligns with previous research proposing household transportation options as a key determinant for active school travel (Lu et al., 2014). Regarding the findings from cluster analysis, which showed that adolescents in C6 reported both the highest autonomy satisfaction as well as the highest active travel (Renninger, Bachner, et al., 2023), it would be interesting to investigate whether disparities in the number of available travel modes existed between clusters. Further, future research needs to take into account whether a travel mode choice is habitually initiated or

based on conscious decision-making. Although habits are believed to develop during adolescence (i.e., Mikkelsen et al., 2019), findings from the qualitative study suggest that habits have already been established for traveling to some destinations (Renninger, Reimers, et al., 2023). Thus, the interplay between habit and the various behavioral regulations is of particular interest for understanding travel behavior as well as behavior change. Regarding variables specific to SDT research, autonomy support is of particular interest (Burgueño, González-Cutre, Sevil-Serrano, Herrador-Colmenero, Segura-Díaz, Medina-Casaubón, & Chillón, 2020) to develop a holistic understanding of the motivational mechanisms underlying travel mode choices. In particular, with regard to our research, this can contribute to understanding the development and composition of the motivational profiles and the motivation–active travel relationship. Additionally, as multiple contextual motivations might influence travel behavior (Vallerand, 1997, 2007), future research might benefit from including various relevant contextual motivations, such as motivation for pro-environmental behavior or physical activity, to explain active travel behavior.

Recognizing the limitations of the present work, future research can improve the current understanding of adolescents' motivation for active travel. Against the theoretical background established for the ARRIVE study (Reimers et al., 2022), the present research is currently limited to examining the individual factor "motivation" as a determinant of adolescents' active travel. However, to fulfill the demand of gaining a comprehensive understanding of adolescents' active travel, subsequent investigations should incorporate adolescents' perception of the environment as well as parental involvement in adolescents' travel mode choices (Reimers et al., 2022). Addressing parental barrier perceptions, previous research found that children's motivation helped to reduce parents' barriers toward active travel (Rutberg & Lindqvist, 2018). Therefore, it would be exciting to assess the interactive dynamics between parental perceived barriers, adolescents' motivation, and their impact on travel mode decisions. Further, previous research underlines the influence of adolescents' perceived environment (e.g., safety, infrastructure, walkability, and urban aesthetics) on travel mode decisions (Klos, Eberhardt, et al., 2023; Klos et al., 2024). Consequently, investigating the relationships between motivation and perceived environment can enhance the comprehensive understanding of the determinants influencing travel mode choices, thus informing targeted policy making.

Although travel modes were assessed individually (e.g., walking, cycling, car, bus, train) within the ARRIVE study (Reimers et al., 2022), we collapsed the modes into "active" and "passive" travel for quantitative analyses. This procedure is in line with most studies in the field of travel behavior (Klos, Burchartz, et al., 2023; Lam et al., 2023). However, analyzing motivation for

each mode individually might produce new knowledge, specifically given the findings from our qualitative study, where adolescents considered each mode individually during decision-making (Renninger, Reimers, et al., 2023).

Addressing the research's limitation of its cross-sectional design, longitudinal research is needed to provide more comprehensive insights into the complex interplay of autonomous and controlled types of motivation. Considering the findings discussed in the previous chapters, it seems tempting to promote extrinsic motivation, eventually even low internalized types. However, one should question the long-term implications that might arise from this. Longitudinal research will contribute to understanding the impact of controlled motivation on well-being and how motivation development can be optimized for maintaining active travel.

Lastly, methodological implications arise from the presented research that can inform future research. This thesis provides the first valid questionnaire to assess adolescents' behavioral regulation in general active travel in the German language (Renninger et al., 2022). Both the theoretical consideration from the Hierarchical Model of Intrinsic and Extrinsic Motivation (Vallerand, 1997, 2007) and the empirical findings regarding the significance of the identified motivational clusters to explain destination-specific travel active behavior (Renninger, Bachner, et al., 2023) hold implications for assessing motivation for active travel. They suggest that the questionnaire (as validated in Renninger et al., 2022) designed to assess motivation for general active travel (i.e., not confined to a particular destination such as school) is suitable for application across diverse travel destinations. This will facilitate future research, particularly in terms of ease of use, as only one questionnaire is required to assess motivation for active travel to evaluate multiple relationships between motivation and travel behavior to various destinations. Such analysis of contextual motivation for general active travel with multiple destination-specific active travel behavior should specifically be included in intervention studies. Considering that travel mode choices are highly context-dependent (Lam et al., 2023; Renninger, Reimers, et al., 2023), such analyses could help to clarify whether interventions to promote for instance motivation for active travel to school can translate to increased active travel to other destinations.

Regarding the variable-centered and person-centered approaches to analyze the relationship of motivation with active travel behavior, the findings enable a comprehensive view by including both approaches. This indicates that integrating both approaches provides the most detailed understanding of motivation, however, methodology is best guided by the research question under investigation. Following on this, further implications emerge when emphasizing a sex/gender-sensitive approach. While no (significant) association was

identified between sex/gender and cluster membership (Renninger, Bachner, et al., 2023), differences emerged in the interaction of active travel and behavioral regulations in boys and girls (Renninger et al., 2022). Drawing on previous research (Gillison et al., 2009), the reasons underlying the behavioral regulations might differ between boys and girls, questioning the unique motives of boys and girls within the same cluster. This indicates the need of investigating motivational clusters separately for boys and girls, as well as understanding their distinct experiences of the behavioral regulations.

5 Conclusion

This thesis advances the knowledge of motivation for general active travel in the decision-making on travel mode choice. Although choosing an active travel mode is highly destination-dependent, motivation for general active travel is associated with destination-specific active travel. Thereby, aiming for high motivation (quantity) for active travel to reduce amotivation appears essential. Initially, it does not seem to be decisive whether this includes autonomous or controlled types of motivation. Specifically recognizing the potential to break "unhealthy" habits, controlled types of motivation may serve as a promising initial step in becoming familiar with new behaviors. Nevertheless, the potential long-term implications of promoting controlled types of motivation need to be considered. Given that i) highly internalized extrinsic motivation is positively (and significantly) associated with active travel (Renninger et al., 2022), ii) high autonomous profiles are associated with higher active travel (Renninger, Bachner, et al., 2023), and iii) autonomous motivation might influence travel mode choice through the attitude of the specific travel mode (Renninger, Reimers, et al., 2023), fostering high internalization of extrinsic motivation appears crucial for long-term adherence. Appropriate behavior-change techniques can support the satisfaction of autonomy, competence, and relatedness, which are essential for internalizing motivation. Although motivation helped explain adolescents' travel behavior, further research is required to address interactive dynamics of adolescents' motivation. To gain a more comprehensive understanding of adolescents' decision-making on travel mode choice additional relevant determinants need to be considered.

References

Abu-Omar, K., Chevance, G., Tcymbal, A., Gelius, P., & Messing, S. (2023). Physical activity promotion, human and planetary health – a conceptual framework and suggested research priorities. *The Journal of Climate Change and Health, 13*, 100262. doi:10.1016/j.joclim.2023.100262

Alves, J. G. B., & Alves, G. V. (2019). Effects of physical activity on children's growth. *Journal de Pediatria, 95 Supplement 1*, 72-78. doi:10.1016/j.jped.2018.11.003

Anthony, A. L., Thomas, H., Anna, G., Yvonne, K., & Christopher, M. (2021). Associations of active travel with adiposity among children and socioeconomic differentials: a longitudinal study. *BMJ Open, 11*(1), e036041. doi:10.1136/bmjopen-2019-036041

Aranda-Balboa, M. J., Chillón, P., Saucedo-Araujo, R. G., Molina-García, J., & Huertas-Delgado, F. J. (2021). Children and Parental Barriers to Active Commuting to School: A Comparison Study. *International Journal of Environmental Research and Public Health, 18*(5). doi:10.3390/ijerph18052504

Aranda-Balboa, M. J., Huertas-Delgado, F. J., Herrador-Colmenero, M., Cardon, G., & Chillón, P. (2020). Parental barriers to active transport to school: a systematic review. *International Journal of Public Health, 65*(1), 87-98. doi:10.1007/s00038-019-01313-1

Biddle, S. J. H., & Asare, M. (2011). Physical activity and mental health in children and adolescents: a review of reviews. *British Journal of Sports Medicine, 45*(11), 886-895. doi:10.1136/bjsports-2011-090185

Brand, C., Dons, E., Anaya-Boig, E., Avila-Palencia, I., Clark, A., de Nazelle, A., . . . Int Panis, L. (2021). The climate change mitigation effects of daily active travel in cities. *Transportation Research Part D: Transport and Environment, 93*, 102764. doi:10.1016/j.trd.2021.102764

Brand, C., Götschi, T., Dons, E., Gerike, R., Anaya-Boig, E., Avila-Palencia, I., . . . Nieuwenhuijsen, M. J. (2021). The climate change mitigation impacts of active travel: Evidence from a longitudinal panel study in seven European cities. *Global Environmental Change, 67*, 102224. doi:10.1016/j.gloenvcha.2021.102224

Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology, 3*(2), 77-101. doi:10.1191/1478088706qp063oa

Braun, V., Clarke, V., & Weate, P. (2016). Using thematic analysis in sport and exercise research. In B. Smith & A. C. Sparkes (Eds.), *Routledge handbook of qualitative research in sport and exercise* (pp. 191-205). London: Routledge.

Bucksch, J., Häußler, A., Schneider, K., Finne, E., Schmidt, K., Dadacynski, K., & Sudeck, G. (2020). Physical activity and dietary habits of older children and adolescents in Germany - Cross-sectional results of the 2017/18 HBSC study and trends. *Journal of Health Monitoring, 5*(3), 21-36. doi:10.25646/6900

Budayan, C., Dikmen, I., & Birgonul, M. T. (2009). Comparing the performance of traditional cluster analysis, self-organizing maps and fuzzy C-means method for strategic grouping. *Expert Systems with Applications, 36*(9), 11772-11781. doi:10.1016/j.eswa.2009.04.022

Burgueño, R., González-Cutre, D., Sevil-Serrano, J., Herrador-Colmenero, M., Segura-Díaz, J. M., Medina-Casaubón, J., & Chillon, P. (2020). Validation of the Basic Psychological Need Satisfaction in Active Commuting to and from School (BPNS-ACS) Scale in Spanish young people. *Journal of Transport & Health, 16*, 100825. doi:10.1016/j.jth.2020.100825

Burgueño, R., González-Cutre, D., Sevil-Serrano, J., Herrador-Colmenero, M., Segura-Díaz, J. M., Medina-Casaubón, J., & Chillón, P. (2019). Understanding the motivational processes involved in adolescents' active commuting behaviour: Development and validation of the Behavioural Regulation in Active Commuting to and from School (BR-ACS) Questionnaire. *Transportation Research Part F: Traffic Psychology and Behaviour, 62*, 615-625. doi:10.1016/j.trf.2019.02.016

Burgueño, R., González-Cutre, D., Sevil-Serrano, J., Herrador-Colmenero, M., Segura-Díaz, J. M., Medina-Casaubón, J., & Chillón, P. (2020). Psychometric properties of the teachers', parents' and peers' versions of the Perceived Autonomy Support Scale for Active Commuting to and from School (PASS-ACS) in children and adolescents. *Travel Behaviour and Society, 20*, 322-330. doi:10.1016/j.tbs.2020.05.002

Burgueño, R., Lindqvist, A.-K., Nyberg, L., Chillon, P., & Rutberg, S. (2023). Basic psychological need satisfaction in active commuting to and from school BPNS-ACS(SWE). *Journal of Transport & Health, 30*, 101618. doi:10.1016/j.jth.2023.101618

Burgueño, R., Rutberg, S., Nyberg, L., Pauelsen, M., Chillon, P., & Lindqvist, A.-K. (2022). Adapting the behavioral regulation in active commuting to and from school questionnaire in Sweden: BR-ACS(SWE). *Transportation Research Interdisciplinary Perspectives, 16*, 100721. doi:10.1016/j.trip.2022.100721

Carlin, A., Murphy, M. H., & Gallagher, A. M. (2016). Do Interventions to Increase Walking Work? A Systematic Review of Interventions in Children and Adolescents. *Sports Medicine, 46*(4), 515-530. doi:10.1007/s40279-015-0432-6

Chillón, P., Ortega, F. B., Ruiz, J. R., Veidebaum, T., Oja, L., Mäestu, J., & Sjöström, M. (2010). Active commuting to school in children and adolescents: An opportunity to increase physical activity and fitness. *Scandinavian Journal of Public Health, 38*(8), 873-879. doi:10.1177/1403494810384427

Clarke, V., & Braun, V. (2013). *Successful qualitative research: A practical guide for beginners*. London: Sage.

Corder, K., Winpenny, E., Love, R., Brown, H. E., White, M., & Sluijs, E. V. (2019). Change in physical activity from adolescence to early adulthood: a systematic review and meta-analysis of longitudinal cohort studies. *Br J Sports Med, 53*(8), 496-503. doi:10.1136/bjsports-2016-097330

Corral-Abós, A., Aibar, A., Estrada-Tenorio, S., Julián, J. A., Ibor, E., & Zaragoza, J. (2021). Implications of school type for active commuting to school in primary education students. *Travel Behaviour and Society, 24*, 143-151. doi:10.1016/j.tbs.2021.03.007

Costa, J., Adamakis, M., O'Brien, W., & Martins, J. (2020). A Scoping Review of Children and Adolescents' Active Travel in Ireland. *International Journal of Environmental Research and Public Health, 17*(6), 2016. doi:10.3390/ijerph17062016

Dalene, K. E., Anderssen, S. A., Andersen, L. B., Steene-Johannessen, J., Ekelund, U., Hansen, B. H., & Kolle, E. (2018). Cross-sectional and prospective associations between sleep, screen time, active school travel, sports/exercise participation and physical activity in children and adolescents. *BMC Public Health, 18*(1), 705. doi:10.1186/s12889-018-5610-7

Davies, D. L., & Bouldin, D. W. (1979). A Cluster Separation Measure. *IEEE Transactions on Pattern Analysis and Machine Intelligence, PAMI-1*(2), 224-227. doi:10.1109/TPAMI.1979.4766909

de Greeff, J. W., Bosker, R. J., Oosterlaan, J., Visscher, C., & Hartman, E. (2018). Effects of physical activity on executive functions, attention and academic performance in preadolescent children: a meta-analysis. *Journal of Science and Medicine in Sport, 21*(5), 501-507. doi:10.1016/j.jsams.2017.09.595

Deci, E. L., & Ryan, R. M. (2000). The "What" and "Why" of Goal Pursuits: Human Needs and the Self-Determination of Behavior. *Psychological Inquiry, 11*(4), 227-268. doi:10.1207/S15327965PLI1104_01

Deci, E. L., & Ryan, R. M. (2008). Facilitating optimal motivation and psychological well-being across life's domains. *Canadian Psychology / Psychologie canadienne, 49*(1), 14-23. doi:10.1037/0708-5591.49.1.14

Finger, J. D., Varnaccia, G., Borrmann, A., Lange, C., & Mensink, G. (2018). Körperliche Aktivität von Kindern und Jugendlichen in Deutschland – Querschnittergebnisse aus KiGGS Welle 2 und Trends. *Journal of Health Monitoring, 3*(1). doi:10.17886/rki-gbe-2018-006

Fitch, D. T., Rhemtulla, M., & Handy, S. L. (2019). The relation of the road environment and bicycling attitudes to usual travel mode to school in teenagers. *Transportation Research Part A: Policy and Practice, 123*, 35-53. doi:10.1016/j.tra.2018.06.013

Forsberg, H., Rutberg, S., Mikaelsson, K., & Lindqvist, A.-K. (2020). It's about being the good parent: exploring attitudes and beliefs towards active school transportation. *International Journal of Circumpolar Health, 79*(1), 1798113. doi:10.1080/22423982.2020.1798113

Friederichs, S. A. H., Bolman, C., Oenema, A., & Lechner, L. (2015). Profiling physical activity motivation based on self-determination theory: a cluster analysis approach. *BMC Psychology, 3*(1), 1. doi:10.1186/s40359-015-0059-2

Gálvez-Fernández, P., Herrador-Colmenero, M., Esteban-Cornejo, I., Castro-Piñero, J., Molina-García, J., Queralt, A., . . . Chillón, P. (2021). Active commuting to school among 36,781 Spanish children and adolescents: A temporal trend study. *Scandinavian Journal of Medicine & Science in Sports, 31*(4), 914-924. doi:10.1111/sms.13917

Gardner, B. (2015). A review and analysis of the use of 'habit' in understanding, predicting and influencing health-related behaviour. *Health Psychology Review, 9*(3), 277-295. doi:10.1080/17437199.2013.876238

Gardner, B., & Lally, P. (2013). Does intrinsic motivation strengthen physical activity habit? Modeling relationships between self-determination, past behaviour, and habit strength. *Journal of Behavioral Medicine, 36*(5), 488-497. doi:10.1007/s10865-012-9442-0

Gardner, B., & Lally, P. (2018). Modelling Habit Formation and Its Determinants. In B. Verplanken (Ed.), *The Psychology of Habit: Theory, Mechanisms, Change, and Contexts* (pp. 207-229). Cham: Springer International Publishing.

Gillison, F. B., Osborn, M., Standage, M., & Skevington, S. (2009). Exploring the experience of introjected regulation for exercise across gender in adolescence. *Psychology of Sport and Exercise, 10*(3), 309-319. doi:10.1016/j.psychsport.2008.10.004

Gillison, F. B., Rouse, P., Standage, M., Sebire, S. J., & Ryan, R. M. (2019). A meta-analysis of techniques to promote motivation for health behaviour change from a self-determination theory perspective. *Health Psychology Review, 13*(1), 110-130. doi:10.1080/17437199.2018.1534071

Gillison, F. B., Standage, M., & Skevington, S. M. (2011). Motivation and Body-Related Factors as Discriminators of Change in Adolescents' Exercise Behavior Profiles. *Journal of Adolescent Health, 48*(1), 44-51. doi:10.1016/j.jadohealth.2010.05.006

González-Cutre, D., Sicilia, Á., & Fernández, A. (2010). [Toward a deeper understanding of motivation towards exercise: measurement of integrated regulation in the Spanish context]. *Psicothema, 22*(4), 841-847.

Gössling, S., Nicolosi, J., & Litman, T. (2021). The Health Cost of Transport in Cities. *Current Environmental Health Reports, 8*(2), 196-201. doi:10.1007/s40572-021-00308-6

Götschi, T., de Nazelle, A., Brand, C., Gerike, R., Alasya, B., Anaya, E., . . . on behalf of the, P. C. (2017). Towards a Comprehensive Conceptual Framework of Active Travel Behavior: a Review and Synthesis of Published Frameworks. *Current Environmental Health Reports, 4*(3), 286-295. doi:10.1007/s40572-017-0149-9

Grize, L., Bringolf-Isler, B., Martin, E., & Braun-Fahrländer, C. (2010). Trend in active transportation to school among Swiss school children and its associated factors: three cross-sectional surveys 1994, 2000 and 2005. *International Journal of Behavioral Nutrition and Physical Activity, 7*(1), 28. doi:10.1186/1479-5868-7-28

Sex/Gender Methods Group. Why sex and gender matter in health research synthesis. Retrieved from https://methods.cochrane.org/equity/sex-and-gender-analysis

Gualdi-Russo, E., Rinaldo, N., & Zaccagni, L. (2022). Physical Activity and Body Image Perception in Adolescents: A Systematic Review. *International Journal of Environmental Research and Public Health, 19*(20). doi:10.3390/ijerph192013190

Guthold, R., Stevens, G. A., Riley, L. M., & Bull, F. C. (2020). Global trends in insufficient physical activity among adolescents: a pooled analysis of 298 population-based surveys with 1·6 million participants. *The Lancet Child & Adolescent Health, 4*(1), 23-35. doi:10.1016/s2352-4642(19)30323-2

Hadiwijaya, H., Klimstra, T. A., Vermunt, J. K., Branje, S. J. T., & Meeus, W. H. J. (2017). On the Development of Harmony, Turbulence, and Independence in Parent–Adolescent Relationships: A Five-Wave Longitudinal Study. *Journal of Youth and Adolescence, 46*(8), 1772-1788. doi:10.1007/s10964-016-0627-7

Hagger, M. S. (2019). Habit and physical activity: Theoretical advances, practical implications, and agenda for future research. *Psychology of Sport and Exercise, 42*, 118-129. doi:10.1016/j.psychsport.2018.12.007

Hagger, M. S., & Chatzisarantis, N. L. D. (2007). Self-determination theory and the theory of planned behavior: An integrative approach toward a more complete model of motivation. In *Psychology of motivation.* (pp. 83-98). Hauppauge, NY, US: Nova Science Publishers.

Hagger, M. S., & Chatzisarantis, N. L. D. (2009). Integrating the theory of planned behaviour and self-determination theory in health behaviour: A meta-analysis. *British Journal of Health Psychology, 14*(2), 275-302. doi:10.1348/135910708X373959

Hagger, M. S., & Chatzisarantis, N. L. D. (2014). An Integrated Behavior Change Model for Physical Activity. *Exercise and Sport Sciences Reviews, 42*(2). doi:10.1249/JES.0000000000000008

Hagger, M. S., & Hamilton, K. (2021). General causality orientations in self-determination theory: Meta-analysis and test of a process model. *European Journal of Personality, 35*(5), 710-735. doi:10.1177/0890207020962330

Haug, E., Smith, O. R. F., Bucksch, J., Brindley, C., Pavelka, J., Hamrik, Z., . . . Sigmundová, D. (2021). 12-Year Trends in Active School Transport across Four European Countries—Findings from the Health Behaviour in School-Aged Children (HBSC) Study. *International Journal of Environmental Research and Public Health, 18*(4), 2118. doi:10.3390/ijerph18042118

Henriques-Neto, D., Peralta, M., Garradas, S., Pelegrini, A., Pinto, A. A., Sánchez-Miguel, P. A., & Marques, A. (2020). Active Commuting and Physical Fitness: A Systematic Review. *International Journal of Environmental Research and Public Health, 17*(8). doi:10.3390/ijerph17082721

Herrero-Herrero, M., García-Massó, X., Martínez-Corralo, C., Prades-Piñón, J., & Sanchis-Alfonso, V. (2017). Relationship between the practice of physical activity and quality of movement in adolescents: a screening tool using self-organizing maps. *The Physician and Sportsmedicine, 45*(3), 271-279. doi:10.1080/00913847.2017.1327303

Howard, J. L., Gagné, M., Van den Broeck, A., Guay, F., Chatzisarantis, N., Ntoumanis, N., & Pelletier, L. G. (2020). A review and empirical comparison of motivation scoring methods: An application to self-determination theory. *Motivation and Emotion, 44*(4), 534-548. doi:10.1007/s11031-020-09831-9

Janssen, I., & LeBlanc, A. G. (2010). Systematic review of the health benefits of physical activity and fitness in school-aged children and youth. *International Journal of Behavioral Nutrition and Physical Activity, 7*(1), 40. doi:10.1186/1479-5868-7-40

Kek, C. C., García Bengoechea, E., Spence, J. C., & Mandic, S. (2019). The relationship between transport-to-school habits and physical activity in a sample of New Zealand adolescents. *Journal of Sport and Health Science, 8*(5), 463-470. doi:10.1016/j.jshs.2019.02.006

Khan, A., Mandic, S., & Uddin, R. (2021). Association of active school commuting with physical activity and sedentary behaviour among adolescents: A global perspective from 80 countries. *Journal of Science and Medicine in Sport, 24*(6), 567-572. doi:10.1016/j.jsams.2020.12.002

Kleszczewska, D., Mazur, J., Bucksch, J., Dzielska, A., Brindley, C., & Michalska, A. (2020). Active Transport to School May Reduce Psychosomatic Symptoms in School-Aged Children: Data

from Nine Countries. *International Journal of Environmental Research and Public Health, 17*(23). doi:10.3390/ijerph17238709

Klos, L., Burchartz, A., Niessner, C., Reimers, A. K., Thron, M., Woll, A., & Wäsche, H. (2023). Active school transport routines during school transitions: Socio-structural predictors of changes from childhood into early adulthood. *Health & Place, 81*, 103005. doi:10.1016/j.healthplace.2023.103005

Klos, L., Eberhardt, T., Nigg, C., Niessner, C., Wäsche, H., & Woll, A. (2023). Perceived physical environment and active transport in adolescents: A systematic review. *Journal of Transport & Health, 33*, 101689. doi:10.1016/j.jth.2023.101689

Klos, L., Fiedler, J., Nigg, C., Niessner, C., Wäsche, H., & Woll, A. (2024). Walking and non-motorized vehicle use in adolescents: the role of neighborhood environment perceptions across urbanization levels. *German Journal of Exercise and Sport Research*. doi:10.1007/s12662-023-00931-5

Lam, H. Y., Jayasinghe, S., Ahuja, K. D. K., & Hills, A. P. (2023). Active School Commuting in School Children: A Narrative Review of Current Evidence and Future Research Implications. *International Journal of Environmental Research and Public Health, 20*(20), 6929. doi:10.3390/ijerph20206929

Larouche, R., & Ghekiere, A. (2018). 6 - An Ecological Model of Active Transportation. In R. Larouche (Ed.), *Children's Active Transportation* (pp. 93-103): Elsevier.

Larouche, R., Saunders, T. J., Faulkner, G. E. J., Colley, R., & Tremblay, M. (2014). Associations Between Active School Transport and Physical Activity, Body Composition, and Cardiovascular Fitness: A Systematic Review of 68 Studies. *Journal of Physical Activity and Health, 11*(1), 206-227. doi:10.1123/jpah.2011-0345

Leslie, E., Kremer, P., Toumbourou, J. W., & Williams, J. W. (2010). Gender differences in personal, social and environmental influences on active travel to and from school for Australian adolescents. *Journal of Science and Medicine in Sport, 13*(6), 597-601. doi:10.1016/j.jsams.2010.04.004

Liu, Y., Ge, X., Li, H., Zhang, E., Hu, F., Cai, Y., & Xiang, M. (2023). Physical activity maintenance and increase in Chinese children and adolescents: the role of intrinsic motivation and parental support. *Frontiers in Public Health, 11*. doi:10.3389/fpubh.2023.1175439

Lu, W., McKyer, E. L. J., Lee, C., Goodson, P., Ory, M. G., & Wang, S. (2014). Perceived barriers to children's active commuting to school: a systematic review of empirical, methodological and theoretical evidence. *International Journal of Behavioral Nutrition and Physical Activity, 11*(1), 140. doi:10.1186/s12966-014-0140-x

Lubans, D. R., Boreham, C. A., Kelly, P., & Foster, C. E. (2011). The relationship between active travel to school and health-related fitness in children and adolescents: a systematic review. *International Journal of Behavioral Nutrition and Physical Activity, 8*, 5. doi:10.1186/1479-5868-8-5

Mah, S. K., Nettlefold, L., Macdonald, H. M., Winters, M., Race, D., Voss, C., & McKay, H. A. (2017). Does parental support influence children's active school travel? *Preventive Medicine Reports, 6*, 346-351. doi:10.1016/j.pmedr.2017.04.008

Maltagliati, S., Rebar, A., Fessler, L., Forestier, C., Sarrazin, P., Chalabaev, A., . . . Cheval, B. (2021). Evolution of physical activity habits after a context change: The case of COVID-19 lockdown. *British Journal of Health Psychology, 26*(4), 1135-1154. doi:10.1111/bjhp.12524

Mandic, S., Leon de la Barra, S., García Bengoechea, E., Stevens, E., Flaherty, C., Moore, A., . . . Skidmore, P. (2015). Personal, social and environmental correlates of active transport to school among adolescents in Otago, New Zealand. *Journal of Science and Medicine in Sport, 18*(4), 432-437. doi:10.1016/j.jsams.2014.06.012

Marker, A. M., Steele, R. G., & Noser, A. E. (2018). Physical activity and health-related quality of life in children and adolescents: A systematic review and meta-analysis. *Health Psychology, 37*(10), 893-903. doi:10.1037/hea0000653

Markland, D., & Tobin, V. (2004). A Modification to the Behavioural Regulation in Exercise Questionnaire to Include an Assessment of Amotivation. *Journal of Sport and Exercise Psychology, 26*(2), 191-196. doi:10.1123/jsep.26.2.191

Marques, A., Santos, T., Demetriou, Y., Schönbach, D. M. I., Peralta, M., Lagestad, P., . . . Gouveia, É. R. (2022). Adaptation of the Behavioural Regulation in Active Commuting to School (BR-ACS) Questionnaire in Portuguese Youth. *Children, 9*(2), 182. doi:10.3390/children9020182

Marques, A., Santos, T., Gouveia, É. R., Demetriou, Y., Schönbach, D. M. I., Ferrari, G., . . . Peralta, M. (2021). Translation and Validation of the Basic Psychological Need Satisfaction in Active Commuting to and from School (BPNS-ACS) Scale in Young Portuguese Students. *International Journal of Environmental Research and Public Health, 18*(24), 13091. doi:10.3390/ijerph182413091

Martin-Moraleda, E., Mandic, S., Queralt, A., Romero-Blanco, C., & Aznar, S. (2022). Associations among Active Commuting to School and Prevalence of Obesity in Adolescents: A Systematic Review. *International Journal of Environmental Research and Public Health, 19*(17). doi:10.3390/ijerph191710852

Martins, J., Marques, A., Sarmento, H., & Carreiro da Costa, F. (2015). Adolescents' perspectives on the barriers and facilitators of physical activity: a systematic review of qualitative studies. *Health Education Research, 30*(5), 742-755. doi:10.1093/her/cyv042

Marzi, I., Emmerling, S., Demetriou, Y., Bucksch, J., Schulze, C., Brindley, C., & Reimers, A. K. (2020). Interventions Aiming to Promote Active Commuting in Children and Adolescents: An Evaluation From a Sex/Gender Perspective. *Frontiers in Sports and Active Living, 2*. doi:10.3389/fspor.2020.590857

McMillan, T. E. (2005). Urban Form and a Child's Trip to School: The Current Literature and a Framework for Future Research. *Journal of Planning Literature, 19*(4), 440-456. doi:10.1177/0885412204274173

Melo Riveros, N. A., Cardenas Espitia, B. A., & Aparicio Pico, L. E. (2019). Comparison between K-means and Self-Organizing Maps algorithms used for diagnosis spinal column patients. *Informatics in Medicine Unlocked, 16*, 100206. doi:10.1016/j.imu.2019.100206

Michie, S., Carey, R. N., Johnston, M., Rothman, A. J., de Bruin, M., Kelly, M. P., & Connell, L. E. (2017). From Theory-Inspired to Theory-Based Interventions: A Protocol for Developing and Testing a Methodology for Linking Behaviour Change Techniques to Theoretical Mechanisms of Action. *Annals of Behavioral Medicine, 52*(6), 501-512. doi:10.1007/s12160-016-9816-6

Mikkelsen, B., Williams, J., Rakovac, I., Wickramasinghe, K., Hennis, A., Shin, H.-R., . . . Breda, J. (2019). Life course approach to prevention and control of non-communicable diseases. *BMJ, 364*, l257. doi:10.1136/bmj.l257

Milfont, T. L., & Fischer, R. (2010). Testing measurement invariance across groups: applications in cross-cultural research. *International Journal of Psychological Research, 3*(1), 111-130. doi:10.21500/20112084.857

Mitra, R. (2013). Independent Mobility and Mode Choice for School Transportation: A Review and Framework for Future Research. *Transport Reviews, 33*(1), 21-43. doi:10.1080/01441647.2012.743490

Molina-García, J., Menescardi, C., Estevan, I., Martínez-Bello, V., & Queralt, A. (2019). Neighborhood Built Environment and Socioeconomic Status are Associated with Active Commuting and Sedentary Behavior, but not with Leisure-Time Physical Activity, in University Students. *International Journal of Environmental Research and Public Health, 16*(17), 3176. doi:10.3390/ijerph16173176

Neves, A., & Brand, C. (2019). Assessing the potential for carbon emissions savings from replacing short car trips with walking and cycling using a mixed GPS-travel diary approach. *Transportation Research Part A: Policy and Practice, 123*, 130-146. doi:10.1016/j.tra.2018.08.022

Ng, J. Y. Y., Ntoumanis, N., Thøgersen-Ntoumani, C., Deci, E. L., Ryan, R. M., Duda, J. L., & Williams, G. C. (2012). Self-Determination Theory Applied to Health Contexts:A Meta-Analysis. *Perspectives on Psychological Science, 7*(4), 325-340. doi:10.1177/1745691612447309

Nobis, C., & Kuhnimhof, T. (2018). *Mobilität in Deutschland – MiD Ergebnisbericht. Studie von infas, DLR, IVT und infas 360 im Auftrag des Bundesministers für Verkehr und digitale Infrastruktur (FE-Nr. 70.904/15).* Retrieved from Bonn, Berlin: www.mobilitaet-in-deutschland.de

Ntoumanis, N., Ng, J. Y. Y., Prestwich, A., Quested, E., Hancox, J. E., Thøgersen-Ntoumani, C., . . . Williams, G. C. (2021). A meta-analysis of self-determination theory-informed intervention studies in the health domain: effects on motivation, health behavior, physical, and psychological health. *Health Psychology Review, 15*(2), 214-244. doi:10.1080/17437199.2020.1718529

Olsen, J. R., Mitchell, R., Mutrie, N., Foley, L., & Ogilvie, D. (2017). Population levels of, and inequalities in, active travel: A national, cross-sectional study of adults in Scotland. *Preventive Medicine Reports, 8*, 129-134. doi:10.1016/j.pmedr.2017.09.008

Owen, K. B., Smith, J., Lubans, D. R., Ng, J. Y. Y., & Lonsdale, C. (2014). Self-determined motivation and physical activity in children and adolescents: A systematic review and meta-analysis. *Preventive Medicine, 67*, 270-279. doi:10.1016/j.ypmed.2014.07.033

Pang, B., Kubacki, K., & Rundle-Thiele, S. (2017). Promoting active travel to school: a systematic review (2010-2016). *BMC Public Health, 17*(1), 638. doi:10.1186/s12889-017-4648-2

Panter, J. R., Jones, A. P., & van Sluijs, E. M. (2008). Environmental determinants of active travel in youth: a review and framework for future research. *International Journal of Behavioral Nutrition and Physical Activity, 5*, 34. doi:10.1186/1479-5868-5-34

Pellicer-Chenoll, M., Garcia-Massó, X., Morales, J., Serra-Añó, P., Solana-Tramunt, M., González, L.-M., & Toca-Herrera, J.-L. (2015). Physical activity, physical fitness and academic achievement in adolescents: a self-organizing maps approach. *Health Education Research, 30*(3), 436-448. doi:10.1093/her/cyv016

Poitras, V. J., Gray, C. E., Borghese, M. M., Carson, V., Chaput, J.-P., Janssen, I., . . . Tremblay, M. S. (2016). Systematic review of the relationships between objectively measured physical activity and health indicators in school-aged children and youth. *Applied Physiology, Nutrition, and Metabolism, 41*(6 (Suppl. 3)), S197-S239. doi:10.1139/apnm-2015-0663 %M 27306431

Pont, K., Ziviani, J., Wadley, D., & Abbott, R. (2011). The Model of Children's Active Travel (M-CAT): A conceptual framework for examining factors influencing children's active travel. *Australian Occupational Therapy Journal, 58*(3), 138-144. doi:10.1111/j.1440-1630.2010.00865.x

Prestwich, A., Sniehotta, F. F., Whittington, C., Dombrowski, S. U., Rogers, L., & Michie, S. (2014). Does theory influence the effectiveness of health behavior interventions? Meta-analysis. *Health Psychology, 33*(5), 465-474. doi:10.1037/a0032853

Prince, S. A., Butler, G. P., Rao, D. P., & Thompson, W. (2019). Evidence synthesis - Where are children and adults physically active and sedentary? - a rapid review of location-based studies. *Health Promotion and Chronic Disease Prevention in Canada, 39*(3), 67-103. doi:10.24095/hpcdp.39.3.01

Rausch Osthoff, A.-K. (2017). Behavioural Regulation in Exercise Questionnaire (BREQ-3)-Deutsche Version. Retrieved from https://digitalcollection.zhaw.ch/bitstream/11475/1230/1/BREQ3-G.pdf

Reimers, A. K., Marzi, I., Beck, F., Engels, E., Renninger, D., Buttazzoni, A., . . . Demetriou, Y. (2022). Active travel behaviour in the family environment: protocol for the mixed-methods cross-sectional ARRIVE study. *BMJ Open, 12*(2), e056383. doi:10.1136/bmjopen-2021-056383

Reimers, A. K., Marzi, I., Schmidt, S. C. E., Niessner, C., Oriwol, D., Worth, A., & Woll, A. (2021). Trends in active commuting to school from 2003 to 2017 among children and adolescents from Germany: the MoMo Study. *European Journal of Public Health, 31*(2), 373-378. doi:10.1093/eurpub/ckaa141

Rejeb, R., Bouscasse, H., Chalabaev, A., & Mathy, S. (2023). What is the role of active mobility habits in the relationship between self-determination and modal shift intentions? A mediation analysis. *Transportation Research Part F: Traffic Psychology and Behaviour, 99*, 289-305. doi:10.1016/j.trf.2023.10.004

Renninger, D., Bachner, J., García-Massó, X., Molina-García, J., Reimers, A. K., Marzi, I., . . . Demetriou, Y. (2023). Motivation and Basic Psychological Needs Satisfaction in Active Travel to Different Destinations: A Cluster Analysis with Adolescents Living in Germany. *Behavioral Sciences, 13*(3), 272. doi:10.3390/bs13030272

Renninger, D., Kelso, A., Reimers, A. K., Marzi, I., Beck, F., Engels, E. S., . . . Demetriou, Y. (2022). Motivation and active travel in adolescent girls and boys in Germany – Findings from the ARRIVE study. *Transportation Research Part F: Traffic Psychology and Behaviour, 90*, 425-437. doi:10.1016/j.trf.2022.09.015

Renninger, D., Reimers, A. K., Marzi, I., Beck, F., Krieger, C., & Demetriou, Y. (2023). How do adolescents experience the decision-making process on travel mode choice? *Health Promotion International, 38*(6). doi:10.1093/heapro/daad147

Reuter, M., Diehl, K., Richter, M., Sundmacher, L., Hövener, C., Spallek, J., & Dragano, N. (2024). A longitudinal analysis of health inequalities from adolescence to young adulthood and their underlying causes. *Advances in Life Course Research, 59*, 100593. doi:10.1016/j.alcr.2024.100593

Rodriguez-Ayllon, M., Cadenas-Sánchez, C., Estévez-López, F., Muñoz, N. E., Mora-Gonzalez, J., Migueles, J. H., . . . Esteban-Cornejo, I. (2019). Role of Physical Activity and Sedentary Behavior in the Mental Health of Preschoolers, Children and Adolescents: A Systematic Review and Meta-Analysis. *Sports Medicine, 49*(9), 1383-1410. doi:10.1007/s40279-019-01099-5

Rutberg, S., & Lindqvist, A.-K. (2018). Children's motivation overcame parental hesitation: active school transportation in Sweden. *Health Promotion International, 34*(6), 1149-1156. doi:10.1093/heapro/day083

Ryan, R. M., & Deci, E. L. (2000). Self-determination theory and the facilitation of intrinsic motivation, social development, and well-being. *American Psychologist, 55*(1), 68-78. doi:10.1037/0003-066X.55.1.68

Ryan, R. M., & Deci, E. L. (2017). *Self-determination theory: Basic psychological needs in motivation, development, and wellness*: Guilford publications.

Ryan, R. M., & Deci, E. L. (2020). Intrinsic and extrinsic motivation from a self-determination theory perspective: Definitions, theory, practices, and future directions. *Contemporary Educational Psychology, 61*, 101860. doi:10.1016/j.cedpsych.2020.101860

Ryan, R. M., & Deci, E. L. (2022). Self-determination theory. In F. Maggino (Ed.), *Encyclopedia of quality of life and well-being research* (pp. 1-7): Springer.

Salvo, D., Jáuregui, A., Adlakha, D., Sarmiento, O. L., & Reis, R. S. (2023). When Moving Is the Only Option: The Role of Necessity Versus Choice for Understanding and Promoting Physical Activity in Low- and Middle-Income Countries. *Annual Review of Public Health, 44*(1), 151-169. doi:10.1146/annurev-publhealth-071321-042211

Schlund, A., Reimers, A. K., Bucksch, J., Brindley, C., Schulze, C., Puil, L., . . . Demetriou, Y. (2021). Do Intervention Studies to Promote Physical Activity and Reduce Sedentary Behavior in Children and Adolescents Take Sex/Gender Into Account? A Systematic Review. *Journal of Physical Activity and Health, 18*(4), 461-468. doi:10.1123/jpah.2020-0666

Schoeppe, S., Duncan, M. J., Badland, H., Oliver, M., & Curtis, C. (2013). Associations of children's independent mobility and active travel with physical activity, sedentary behaviour and weight status: a systematic review. *Journal of Science and Medicine in Sport, 16*(4), 312-319. doi:10.1016/j.jsams.2012.11.001

Schönbach, D. M. I., Altenburg, T. M., Marques, A., Chinapaw, M. J. M., & Demetriou, Y. (2020). Strategies and effects of school-based interventions to promote active school transportation

by bicycle among children and adolescents: a systematic review. *International Journal of Behavioral Nutrition and Physical Activity, 17*(1), 138. doi:10.1186/s12966-020-01035-1

Schönbach, D. M. I., Brindley, C., Reimers, A. K., Marques, A., & Demetriou, Y. (2020). Socio-Demographic Correlates of Cycling to School among 12- to 15-Year Olds in Southern Germany. *International Journal of Environmental Research and Public Health, 17*(24), 9269. doi:10.3390/ijerph17249269

Shaw, B., Bicket, M., Elliott, B., Fagan-Watson, B., Mocca, E., & Hillman, M. (2015). *Children's Independent Mobility: an international comparison and recommendations for action*. Retrieved from https://www.nuffieldfoundation.org/sites/default/files/files/7350_PSI_Report_CIM_final.pdf

Standage, M., Gillison, F. B., Ntoumanis, N., & Treasure, D. C. (2012). Predicting Students' Physical Activity and Health-Related Well-Being: A Prospective Cross-Domain Investigation of Motivation Across School Physical Education and Exercise Settings. *Journal of Sport and Exercise Psychology, 34*(1), 37-60. doi:10.1123/jsep.34.1.37

Stark, J., Singleton, P. A., & Uhlmann, T. (2019). Exploring children's school travel, psychological well-being, and travel-related attitudes: Evidence from primary and secondary school children in Vienna, Austria. *Travel Behaviour and Society, 16*, 118-130. doi:10.1016/j.tbs.2019.05.001

Steene-Johannessen, J., Hansen, B. H., Dalene, K. E., Kolle, E., Northstone, K., Møller, N. C., . . . Ekelund, U. (2020). Variations in accelerometry measured physical activity and sedentary time across Europe - harmonized analyses of 47,497 children and adolescents. *International Journal of Behavioral Nutrition and Physical Activity, 17*(1), 38. doi:10.1186/s12966-020-00930-x

Teixeira, P. J., Marques, M. M., Silva, M. N., Brunet, J., Duda, J. L., Haerens, L., . . . Hagger, M. S. (2020). A classification of motivation and behavior change techniques used in self-determination theory-based interventions in health contexts. *Motivation Science, 6*(4), 438-455. doi:10.1037/mot0000172

Telama, R., Yang, X., Leskinen, E., Kankaanpää, A., Hirvensalo, M., Tammelin, T., . . . Raitakari, O. T. (2014). Tracking of physical activity from early childhood through youth into adulthood. *Med Sci Sports Exerc, 46*(5), 955-962. doi:10.1249/mss.0000000000000181

United Nations. (2015). *Analysis of the transport relevance of each of the 17 SDGs* Retrieved from https://sdgs.un.org/documents/analysis-transport-relevance-each-21286

United Nations. (2016). *Transforming our world: The 2030 agenda for sustainable development*. Retrieved from https://sdgs.un.org/2030agenda

Vallerand, R. J. (1997). Toward A Hierarchical Model of Intrinsic and Extrinsic Motivation. In M. P. Zanna (Ed.), *Advances in Experimental Social Psychology* (Vol. 29, pp. 271-360): Academic Press.

Vallerand, R. J. (2007). A hierarchical model of intrinsic and extrinsic motivation for sport and physical activity. In *Intrinsic motivation and self-determination in exercise and sport.* (pp. 255-279,356-363). Champaign, IL, US: Human Kinetics.

Vansteenkiste, M., & Mouratidis, A. (2016). Emerging Trends and Future Directions for the Field of Motivation Psychology: A Special Issue in Honor of Prof. Dr. Willy Lens. *Psychologica Belgica*. doi:10.5334/pb.354

Vansteenkiste, M., Soenens, B., & Vandereycken, W. (2005). Motivation to change in eating disorder patients: A conceptual clarification on the basis of self-determination theory. *International Journal of Eating Disorders, 37*(3), 207-219. doi:10.1002/eat.20099

Wangzom, D., White, M., & Paay, J. (2023). Perceived Safety Influencing Active Travel to School - A Built Environment Perspective. *International Journal of Environmental Research and Public Health, 20*(2), 1026. doi:10.3390/ijerph20021026

Wehrens, R. (2009). 2.28 - Data Mapping: Linear Methods versus Nonlinear Techniques. In S. D. Brown, R. Tauler, & B. Walczak (Eds.), *Comprehensive Chemometrics* (pp. 619-633). Oxford: Elsevier.

Wex, I., Geserick, M., Leibert, T., Igel, U., Sobek, C., Meigen, C., . . . Vogel, M. (2023). Active school transport in an urban environment:prevalence and perceived barriers. *BMC Public Health, 23*(1), 557. doi:10.1186/s12889-023-15464-7

White, R. L., Olson, R., Parker, P. D., Astell-Burt, T., & Lonsdale, C. (2018). A qualitative investigation of the perceived influence of adolescents' motivation on relationships between domain-specific physical activity and positive and negative affect. *Mental Health and Physical Activity, 14*, 113-120. doi:10.1016/j.mhpa.2018.03.002

White, R. L., Parker, P. D., Lubans, D. R., MacMillan, F., Olson, R., Astell-Burt, T., & Lonsdale, C. (2018). Domain-specific physical activity and affective wellbeing among adolescents: an observational study of the moderating roles of autonomous and controlled motivation. *International Journal of Behavioral Nutrition and Physical Activity, 15*(1), 87. doi:10.1186/s12966-018-0722-0

WHO. (2018a). COP24 special report: health and climate change. Retrieved from https://www.who.int/publications/i/item/cop24-special-report-health-climate-change

WHO. (2018b). *Global action plan on physical activity 2018–2030: more active people for a healthier world*. Geneva: World Health Organization.

WHO. (2020). *WHO guidelines on physical activity and sedentary behaviour*. Genva: World Health Organization.

Wilson, K., Clark, A. F., & Gilliland, J. A. (2018). Understanding child and parent perceptions of barriers influencing children's active school travel. *BMC Public Health, 18*(1), 1053. doi:10.1186/s12889-018-5874-y

Wilson, P. M., Rodgers, W. M., Loitz, C. C., & Scime, G. (2006). "It's Who I Am … Really!' The Importance of Integrated Regulation in Exercise Contexts1. *Journal of Applied Biobehavioral Research, 11*(2), 79-104. doi:10.1111/j.1751-9861.2006.tb00021.x

Wu, X. Y., Han, L. H., Zhang, J. H., Luo, S., Hu, J. W., & Sun, K. (2017). The influence of physical activity, sedentary behavior on health-related quality of life among the general population of children and adolescents: A systematic review. *PLoS One, 12*(11), e0187668. doi:10.1371/journal.pone.0187668

Yang, X., Telama, R., Hirvensalo, M., Tammelin, T., Viikari, J. S. A., & Raitakari, O. T. (2014). Active commuting from youth to adulthood and as a predictor of physical activity in early midlife: The Young Finns Study. *Preventive Medicine, 59*, 5-11. doi:10.1016/j.ypmed.2013.10.019

Attachments
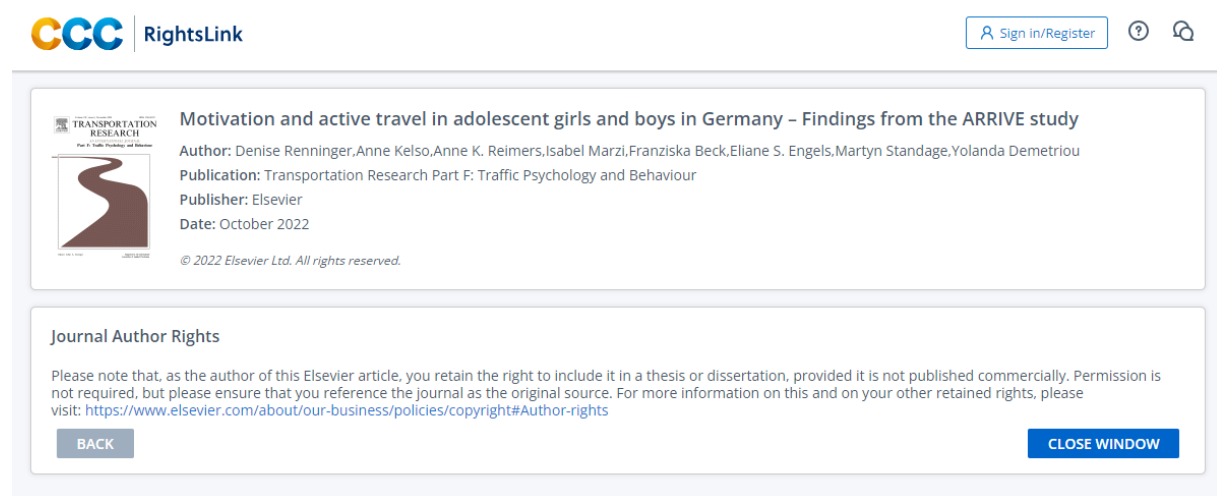
Appendix I: List of Publications

Beck, F., Marzi, I., **Renninger, D.**, Demetriou, Y., Engels, E. S., Niermann, C., & Reimers, A. K. (2023). Associations of parents' and adolescents' active travel behavior across various destinations – a sex/gender analysis. *BMC Public Health*, 23(1), 522. doi:10.1186/s12889-023-15428-x

Marzi, I., Beck, F., Engels, E., **Renninger, D.**, Demetriou, Y., & Reimers, A. K. (2023). Adolescents' travel behavior in Germany: Investigating transport mode choice considering destination, travel distance, and urbanization. *Journal of Transport Geography*, 112, 103694. doi:10.1016/j.jtrangeo.2023.103694

Reimers, A. K., Marzi, I., Beck, F., Engels, E., **Renninger, D.**, Buttazzoni, A., Krieger, C., & Demetriou, Y. (2022). Active travel behaviour in the family environment: protocol for the mixed-methods cross-sectional ARRIVE study. *BMJ Open*, 12(2), e056383. doi:10.1136/bmjopen-2021-056383

Renninger, D., Bachner, J., García-Massó, X., Molina-García, J., Reimers, A. K., Marzi, I., Beck, F., & Demetriou, Y. (2023). Motivation and Basic Psychological Needs Satisfaction in Active Travel to Different Destinations: A Cluster Analysis with Adolescents Living in Germany. *Behavioral Sciences*, 13(3), 272. doi:10.3390/bs13030272

Renninger, D., Kelso, A., Reimers, A. K., Marzi, I., Beck, F., Engels, E. S., Standage, M., & Demetriou, Y. (2022). Motivation and active travel in adolescent girls and boys in Germany – Findings from the ARRIVE study. Transportation Research Part F: Traffic Psychology and Behaviour, 90, 425-437. doi:10.1016/j.trf.2022.09.015

Renninger, D., Reimers, A. K., Marzi, I., Beck, F., Krieger, C., & Demetriou, Y. (2023). How do adolescents experience the decision-making process on travel mode choice? *Health Promotion International, 38*(6). doi:10.1093/heapro/daad147

Renninger, D., Sturm, D. J., Krieger, C., & Demetriou, Y. (2021). Förderung der körperlichen Aktivität von Mädchen im Sportunterricht. *German Journal of Exercise and Sport Research*, 51(2), 222-231. doi:10.1007/s12662-021-00705-x

Renninger, D., Sturm, D. J., Marques, A., Peralta, M., Popovic, S., Gardasevic, J., Masanocic, B., & Demetriou, Y. (2021). Physical Activity and Body-Mass-Index: Do Family, Friends and Teachers Restrain the Risk for Physical Inactivity in Adolescents? *Sustainability*, 13(13), 6992. doi:10.3390/su13136992

Seemüller, S., Beck, F., Tristram, C., Marzi, I., **Renninger, D.**, Demetriou, Y., & Reimers, A. K. (2023). The role of parental environmental self-identity in active travel behavior within parent–adolescent dyads. *German Journal of Exercise and Sport Research*. doi:10.1007/s12662-023-00923-5

Sturm, D. J., Bachner, J., **Renninger, D.**, Haug, S., & Demetriou, Y. (2021). A cluster randomized trial to evaluate need-supportive teaching in physical education on physical activity of sixth-grade girls: A mixed method study. *Psychology of Sport and Exercise*, 54, 101902. doi:10.1016/j.psychsport.2021.101902

Tristram, C., Reimers, A. K., **Renninger, D.**, Beck, F., Demetriou, Y., & Marzi, I. (2023). Parental perspectives on the decision-making process on transport mode choice in adolescents: a qualitative study with mothers and fathers. *Frontiers in Psychology*, 14. doi:10.3389/fpsyg.2023.1227612

Appendix II: Reprint permissions

1. Publication

Renninger, D., Kelso, A., Reimers, A. K., Marzi, I., Beck, F., Engels, E. S., Standage, M., & Demetriou, Y. (2022). Motivation and active travel in adolescent girls and boys in Germany – Findings from the ARRIVE study. *Transportation Research Part F: Traffic Psychology and Behaviour, 90*, 425-437. doi:10.1016/j.trf.2022.09.015

2. Publication

Renninger, D., Bachner, J., García-Massó, X., Molina-García, J., Reimers, A. K., Marzi, I., Beck, F., & Demetriou, Y. (2023). Motivation and Basic Psychological Needs Satisfaction in Active Travel to Different Destinations: A Cluster Analysis with Adolescents Living in Germany. *Behavioral Sciences, 13*(3), 272. doi:10.3390/bs13030272

3. Publication

Renninger, D., Reimers, A. K., Marzi, I., Beck, F., Krieger, C., & Demetriou, Y. (2023). How
do adolescents experience the decision-making process on travel mode choice?
Health Promotion International, 38(6). doi:10.1093/heapro/daad147