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"Another (hard) day moving in the city": Development and validation of the MCSS, a multimodal commuting stress scale

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ABSTRACT

Although most of the literature on stress-related factors uniformly points out several negative health, performance, and safety issues as potential outcomes attributable to a prolonged exposition to stressful situations, the applications of these assumptions to the field of urban mobility (and more specifically to commuting) remain considerably scarce. Indeed, while commuters worldwide usually face daily situations such as traffic jams, dearth of transport choices, crowded public transport services, long trips, and road conflicts, there are only a few studies that have methodologically addressed the issue of commuting stress (CS).

Aim: This paper aims to present in detail the development and validation of the Multimodal Commuting Stress Scale (MCSS), a self-report tool for assessing commuting stress-related factors among urban commuters of different modalities.

Methods: This cross-sectional study retrieved data from a nationwide sample of 1,429 commuters (aged between 18 and 78; average 34.42 years) from all 17 Spanish regions. Data were analyzed through Structural Equation Model-based competitive Confirmatory Factor Analyses, thus testing the psychometric performance of the scale under different structural assumptions, as well as its reliability, consistency, and validity insights.

Results: The outcomes of this study suggest that the developed MCSS has a clear four-dimensional structure, an optimal set of factor loadings, fair goodness-of-fit indexes, and satisfactory internal consistency and reliability. Additionally, validity analyses show that commuting stress factors measured through the MCSS have coherent associations with both physical/mental health indexes and trip-related factors, while it also discriminates commuting stress scores by sex, age, and commuting modality.

Conclusion: All in sum, the findings of this study endorse the suitability of the Multimodal Commuting Stress Scale for measuring stress-related factors affecting urban commuters, as well as to make comparisons among different groups of them.

1. Introduction

Over the last years, transport researchers have consistently argued that travel experiences, particularly when they are persistently negative, may affect people's everyday performance, as well as their health and welfare outcomes (Holland, 2016). Added to the

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persistence of common transport issues in most cities, there are users whose high travel frequency explains an increased number of transport-related threats. This is the case of *commuters*, usually understood in literature as "persons who travel regularly to/from a typical place, such as the workplace, study center, or other destinations" (Diebig et al., 2021).

Indeed, commuters have been stated in previous research as the transport users dealing the most with, among many others, pre-fixed and long travel times, different road risks, and the traditionally coexisting traffic congestion and crowding (Cendales et al., 2023; Cox, Houdmont & Griffiths, 2006). This has given rise to the concept of *commuting stress* (CS), which has been gaining importance during the last few decades, bearing in mind the widespread prevalence of many 'everyday stressors' in transport systems worldwide (Novaco, Stokols, & Milanesi, 1990; Burch, 2015).

1.1. The concept of commuting stress: Theoretical roots and key spheres

Even though its influential factors remain only partly clear, and current definitions still require theoretical consensus, commuting stress has begun to gain ground in literature since the 1990s. According to review studies, the theoretical roots of CS can be traced back to several fields of study, including psychology, sociology, and urban/transport planning (Hennessy, 2008; Holland, 2016).

Nevertheless, due to its stress-related nature, the concept is nowadays addressed through a psychological perspective, for which *commuting stress* is commonly understood in terms of the demands and challenges that individuals face during their daily travel experiences, and their own resources to deal with them (Burch, 2015). This is consistent with what is, perhaps, the most widely agreed definition of "stress" as a concept: an umbrella term representing experiences in which the environmental demands outweigh the individual's perceived psychological and physiological coping abilities (Cohen et al., 2016).

Further, given that most of the first works on commuting stress were conducted within the scope of occupational health psychology, the concept has been greatly influenced by theoretical models of work stress, such as the job demand-control model (JDC; Karasek, 1979) and the cybernetic theory of stress (CTS; Edwards, 1992). In both cases, it is theorized that prolonged negative discrepancies between demands and individual's control (JDC), or between actual-negative and desired states (CTS) should lead individuals to experience physical, affective, and/or cognitive strains (Schaeffer, Street, Singer, & Baum, 1988; Zhou et al., 2017).

Applied to the field of urban mobility, subsequent studies performed from interdisciplinary transportation research perspectives highlight the complex multidimensional interplay among individual, social, and environmental stress-related factors in transit environments (Chatterjee et al., 2020; Koslowsky, 1997; Burch, 2015), which jeopardize the physical and mental health, wellbeing, and even safety of road users (Halonen et al., 2020; Kumagai, Wakamatsu, & Managi, 2021; Burch, 2015; Legrain, Eluru & El-Geneidy, 2015).

Overall, and despite the many conceptual and methodological changes that the concept of CS has undergone since its first advances (and the relative lack of consensus on it), the accumulated evidence tends to characterize commuting stress-related key factors in four "big spheres" which are described below:

1.1.1. Transport crowding and congestion

The first theoretical links of commuting stress have been historically related to adverse environmental conditions experienced by users in transport settings. Particularly, transport overcrowding and its subsequent delays and nuisances have a predominant role in studies from past decades as a core factor enhancing commuting stress (Costa, Pickup & Di Martino, 1988; Koslwosky, 1997). Although traffic congestion cannot be equalized with in-vehicle crowding, the literature has systematically shown strong associations between them, as they impair both users' comfort and subjective travel experience (Burch, 2015; Cox, Houdmont & Griffiths, 2006; Kumagai, Wakamatsu & Managi, 2021).

Moreover, despite the many efforts made during past decades to reduce traffic density, several issues increasing its impedance remain an active challenge across many cities and commuting means (Chatterjee et al., 2020; Rezapour & Richard Ferraro, 2021), thus posing, nowadays, several challenges for both transport systems and transport users (Çolak, Lima & González, 2016; Kumagai, Wakamatsu & Managi, 2021).

In addition, studies conducted after the recent COVID-19 pandemic suggest that, despite the improvement of standard measures such as vehicle ventilation, hygiene, and disinfection, many users have opted for avoiding massive transport means due to both personal concerns, especially fear of contagion, and convenience issues (Anwari et al., 2021; Aydin, Kuşakcı & Deveci, 2022; Awad-Núñez et al., 2021). However, the role of convenience has been majorly addressed from an economic cost-benefit perspective, while recent research outcomes propose that it might be a relevant aspect for explaining subjective assessments of travel experience (Doubleday et al., 2021; Irawan et al., 2021; Useche et al., 2021).

1.1.2. Convenience… or the lack of it

The current literature on travel experiences and commuting stress suggests emerging perspectives on traditional problems, such as transport convenience. While it was approached many decades ago as an economic and trip length cost-benefit balance, contemporary issues such as active travel, well-being, and social identity now partake in the decision to use a certain transportation means, or a set of them (Schäfer et al., 2020; Ogilvie et al., 2016; Oja et al., 2011).

Notwithstanding, and given that infrastructural developments and transport service improvements seldom correspond in time with demand-related trends (Gao et al., 2019; Wang et al., 2019), users of different means for commuting commonly experience several constraints while performing their daily life movements, especially at peak hours and highly demanded city locations (Gottholmseder et al., 2009; Halonen et al., 2020; Lovinsky-Desir et al., 2019; Morris & Hirsch, 2016).

Accordingly, recent studies have raised several concerns about whether the subjective aspects related to convenience (e.g.,

enhancing the family and leisure time available by making systems more efficient) are not yet sufficiently considered within (*i*) the transport offer provided by the mobility systems, nor (*ii*) the study of the travel experience itself (Bai et al., 2021; Alonso et al., 2020; Urhonen, Lie & Aamodt, 2016).

1.1.3. Safety and security in transport

Going even closer in time, and linked to other emerging trends in research, the perceived degrees of safety and security of transport means used for commuting have also been gaining ground as relevant matters to explain stress-related outcomes frequently experienced by urban commuters during the last decade (Chatterjee et al., 2020; Orozco-Fontalvo et al., 2019; Soto, Orozco-Fontalvo & Useche, 2021). In this sense, recent studies provide interesting highlights on the relation between transport safety/security and commuting stress outcomes.

Firstly, it is known that safety perceptions (*e.g.*, perceiving a great risk of suffering a crash) may elicit stressful states and reactions among urban commuters, but especially among commuting drivers (Cendales, Llamazares, & Useche, 2023; Ding, Gebel, Phongsavan, Bauman, & Merom, 2014; Hansson, Mattisson, Björk, Östergren, & Jakobsson, 2011; Wang, Rodríguez, Sarmiento, & Guaje, 2019). However, transport security also seems to count to a non-despicable extent: empirical studies conducted during the past 20 years have been systematically finding that stress reactions to insecurity perceptions and conditions, and especially fear of crime, explain adverse outcomes in both male and female commuters, even though the trend is notably marked towards the second (Macassa et al., 2018; Tandogan & Ilhan, 2016; Macmillan, Nierobisz & Welsh, 2000).

Secondly, it is common to find that behavioral changes resulting from perceived insecurity frequently overlap other daily life tasks of commuters, especially among people with lesser income levels, who do not have access to a private vehicle and continue to depend on public transport (Ceccato & Loukaitou-Sideris, 2021; Ceccato, Langefors & Nässman, 2021; Alonso et al., 2020).

1.1.4. Effects (strains) of commuting stress

Another frequent question just slightly resolved in literature (although frequently addressed as a hypothesis is whether there is something like a psychophysical strain related to, or rather "resulting from" commuting stress. For this point, strain cannot be understood as a factor eliciting commuting stress but, rather, a set of stress-related physical and psychological outcomes of commuting stress (Wiese et al., 2020).

Most psychological theories on stress endorse the assumption that a stressful experience always leads to a stress response regardless of it is whether considered positive, or negative, given its undiscussable relationship to psychophysiological parameters (Cendales et al., 2016; Ursin & Eriksen, 2004). However, the evidence applied to stressful factors highlights the fact that a greater number of stress-related exposures (especially if they are considered recurrent and prolonged over time) may explain negative or hazardous outcomes in terms of both the physical and mental health of individuals, as recently suggested by applied studies dealing with working populations (Cendales, Llamazares, & Useche, 2023; Pérez-Fuentes, Gázquez, Molero, Oropesa, & Martos, 2021; Useche, Cendales, Montoro, & Esteban, 2018a,b; Useche, Montoro, Alonso, & Pastor, 2019).

Overall, these pieces of evidence allow to hypothesize that stressful processes in transit environments could explain negative outcomes, especially considering that transport-related stress has been consistently linked to an increased rate of health complaints in both physical and mental strain symptoms (Hansson et al., 2011; Urhonen, Lie & Aamodt, 2016). Further, and as an interesting figure on CS's negative psychological health outcomes, a recent study performed in eleven different Latin American cities found that even ten more minutes of commuting time can slightly but significantly increase the likelihood to suffer negative mental health outcomes such as depression (Wang et al., 2019).

1.2. Not the same for everybody: The need for a multidimensional approach to commuting stress

Although specific evidence remains scarce for some users as a consequence of the underrepresentation of non-drivers in accumulated literature (which is a very common gap in many areas of traffic psychology – *see* Af Wåhlberg, Barraclough & Freeman, 2015; Useche & Llamazares, 2022), the existing evidence consistently supports the idea that commuting stress is a phenomenon present across different means of transport, and among users traveling for different reasons or motivations (Chatterjee et al., 2020; Lyons & Chatterjee, 2008).

Indeed, various empirical experiences addressing CS impacts state that trip features of different transport means may contribute to explaining differences in both the way and extent to which commuting stress may be experienced (Hoehner et al., 2012; Gottholmseder et al., 2009). For instance, key issues such as the degree of physical activity or effort put into displacements (e.g., walking vs. driving) might contribute to differentiating commuting stress experiences among different trip modalities (Avila-Palencia et al., 2017; Ettema et al., 2011; Jin, Jim, & Jin, 2022; Saunders, Green, Petticrew, Steinbach, & Roberts, 2013).

Also, and besides modalities themselves, trip-related factors such as intensity, length, or complexity can modulate the degree of commuting stress experienced by users, making it important to consider jurisdictional differences, such as modal sharing and trip frequency (Wang et al., 2019; Urhonen, Lie & Aamodt, 2016; Evans & Wener, 2006). For instance, pioneer studies conducted in locations with a high car share such as the United States have highlighted route impedance (e.g., traffic congestion, traffic lights, running out of gas, etc.) as a frequent factor referred to by drivers as a commuting stress elicitor, while studies conducted in locations with greater use of public transport typically highlight to other modal constraints (e.g., waiting times and delays) as common stressors (Costa, Pickup & Di Martino, 1988; Schaeffer et al., 1988). Altogether, these divergences and multiple possible contributing stress-related factors highlight the need for addressing the issue from a multidimensional perspective.

1.3. Study aims and hypotheses

Seeking to provide a suitable and valid self-report-based commuting stress research tool useful to measure this variable under a multidimensional perspective across commuting means, the core aim of this paper was to present in detail the development and validation of the Multimodal Commuting Stress Scale (MCSS).

Considering the theoretical and empirical assumptions mentioned in the background, it was hypothesized that: *a)* the MCSS is adequately adjusted to a four-factor structure, presenting adequate fit indices and fair psychometric indexes within a sample of Spanish commuters using different transport modes for this purpose; and *b)* that the four dimensions of the MCSS have coherent and significant associations with commuters' health and safety-related variables used to contrast their both criterion and convergent validity.

2. Methods

2.1. Study setting

This study used the data retrieved through an electronic questionnaire responded to by a nationwide sample of Spanish urban commuters. They were invited to partake in the study through a pre-existing mailing list shared by various research groups and academic centers in Spain. This means that a non-probabilistic (convenience) sampling method was used. The decision of performing an electronic survey was based on both its practicality and the increased difficulty and unwillingness to perform face-to-face interviews, as part of social distancing and security protocols and guidelines endorsed by research agencies, universities, and research groups.

Bearing in mind that no specific data exists on how Spaniards commute regularly (especially if trip changes related to COVID-19 are considered), the full Spanish census of persons aged over 16 (almost 43.5 million inhabitants for 2020; INE, 2021) was assumed as the population size, estimating an a priori minimum sample size of 670 individuals, assuming a level of confidence of 95%, a maximum margin of error of 5% ($\alpha = 0.050$), and a beta (β) of 0.200 (which allows for 80% power). However, it is worth mentioning that, although the sample had nationwide coverage, it cannot be considered fully representative of the whole population because of the non-probabilistic nature of the sampling procedure, as well as the fact that it was limited to urban commuters. Therefore, the generalizability of the data must be rigorously assumed restricted to this group.

Table 1
Sociodemographic information and commuting trip-based features of participants.

Independent variable	Classification	Frequency	Percentage
Gender	Women	814	57.0%
	Men	615	43.0%
Age Group	Young Adult (≤25)	674	47.2%
	Adult (26–50)	450	31.5%
	Aging Adult (>50)	305	21.3%
Educational level	Primary studies or lower	72	5.1%
	Secondary-high school	234	16.4%
	Technical studies	226	15.8%
	University studies	655	45.8%
	Post-graduate studies	242	16.9%
Occupation	Student	609	42.6%
	Employed	534	37.4%
	Self-employed	106	7.4%
	Unemployed	68	4.8%
	Retired	57	4.0%
	Householding	28	2.0%
	Other	27	1.9%
Main motivation for their urban trips	Daily trips (commuting)	767	53.7%
	Short trip to a specific place	167	11.7%
	Leisure trips (e.g., social events)	164	11.5%
	Going to make exercise (e.g., gym) or sports	254	17.8%
	Housework (e.g., go shopping, picking up children)	76	5.3%
	Part of my job	1	0.1%
Most frequent commuting transport mode	Bus	239	16.7%
	Metro or tram	288	20.2%
	Taxi or VTC	30	2.1%
	Private car	460	32.2%
	Motorized two-wheeler	43	3.0%
	Non-motorized two-wheeler	47	3.3%
	Walking	262	18.3%
	Other	60	4.2%
Daily commuting time (round trip)	<1 h	756	52.9%
	1–1.9 h	610	42.7%
	2–2.9 h	34	2.4%
	3–3.9 h	17	1.2%
	> 4 h	12	0.8%

In terms of the recruitment procedure, all participants received a link including a description of the survey, its aims, and conditions, as well as an informed consent form (highlighting current data treatment & protection policies and the merely scientific use of the research data), which was read and agreed on before proceeding to the questionnaire, being the inclusion criteria the fact of regularly performing urban commuting roundtrips at least sometimes a week. Special emphasis was put on the fact that the data would be only used for research and scientific purposes.

As the e-questionnaire was programmed to be submitted only upon a previous fulfillment of all the obligatory questions, no missing cases resulted from the sampling phase, even though 158 questionnaires were never submitted by participants starting to respond, being consequently discarded from the study. Overall, a total (*n*) of 1,429 participants fulfilled and submitted the electronic form, which represented a response rate of about 55% of the total of approximately 2,600 electronic invitations initially sent.

2.2. Study participants

This cross-sectional research, whose data collection process took place during the year 2021, examined the information retrieved from a full sample of 1,429 Spanish commuters from all 17 Autonomous Communities or regions of the country. About 57% of the participants were women, and 43% men. The full sample was aged $M = 34.42$ ($SD = 14.86$) years. Table 1 contains additional descriptive data on the participants.

2.3. Description of the questionnaire

The electronic form used to retrieve the data for this study was structured into three main parts or sections:

The first part of the electronic survey asked about individual and demographic variables, such as age, gender, educational level, and main occupation. It also contained a brief set of questions on self-rated health information (e.g.), mental and physical health on a [0–10] scale, and information about their weight and height, useful to calculate participants' Body Mass Index (BMI).

Secondly, we used the Multimodal Commuting Stress Scale (MCSS), a self-report questionnaire that measures commuting stress under a multidimensional approach (see section 2.4 for further information). The MCSS follows a frequency-based Likert scale, using response alternatives ranging from 0 = never/hardly ever to 4 = almost always/always.

Structurally, this scale theoretically is composed of 21 items distributed along four commuting stress-related factors of transport, presented in the form of short sub-scales: *Inefficiency and inconvenience* (II) – consisting of 7 items; *Unsafety and insecurity* (UI) – 5 items; *Congestion and crowding* (CC) – 4 items; and *Physical strain* (PS) – 5 items. The item composition and key indexes/coefficients of the questionnaire are presented in Table 3.

Lastly, we inquired about a set of commuting habits and patterns, including the most frequent transport means used for this purpose, the average length of their most common commuting journeys (round trip), and the number of remembered accidents or incidents (regardless of their severity) they suffered during the last five years.

2.4. MCSS development

The scale was developed following a two-phase strategy, following the best practices commonly advised in specialized literature, as well as based on the research team experience (Boateng et al., 2018). A first phase consisted of the questionnaire development. After identifying the core commuting stress-related factors in literature (e.g., traffic congestion, crowds, safety and security issues, common outcomes), the items of the MCSS were created and pooled. The items for Factors 1, 2, and 3 were developed following a generic situational strategy (e.g., *commuting to work/study makes me get up earlier than I should*) and Factor 4 in terms of common stress-related effects (e.g., *physically, I feel a bit tense while making these trips*), since the target populations were multiple groups of road users. The item pool was reviewed and polished by all the research staff members and the language/terminology used was double-checked by an ad-hoc expert (with a broad background in stress research and transportation studies) before conducting the preliminary content validity assessment.

Content validity was assessed by the authors of the study, all of them holding Ph.D. degrees, officially accredited university professors, and with several previous methodological developments and published outcomes in fields compatible with this research (*i.e.*, transport psychology, psychometrics, stress measurement, occupational health). Starting from a set of 30 possible items, each question was individually rated on the basis of their attributed dimensional significance (percentage), keeping those items with an average of $\geq$70%. This resulted in a questionnaire composed of 21 items distributed over 4 different baseline spheres.

In the second phase, the questionnaire was subsequently pilot-tested in a sample of 24 volunteers responding to it in a paper-based format. This was made in order to track its resolution process and to target any possible doubt or confusion in regard to, e.g., the questionnaire instructions, item contents, or response scales. Participants were also encouraged to raise further suggestions, if pertinent. While most pilot partakers expressed full satisfaction with the questionnaire resolution, some of them expressed slight suggestions for the redaction of some items, namely changing a few words and providing examples of "harassment". After conducting the suggested adjustments, the questionnaire was online distributed to a greater study sample, allowing its psychometric analysis and validation procedure.

2.5. Data analysis

Initially, basic data treatment allowed us to carry out a descriptive analysis of the characteristics of the participants and their results

in the additional questionnaires that were used. Afterward, a rigorous procedure assessed the factorial arrangement of the MCSS using competitive CFA-based (confirmatory) analyses using consecutive fit steps (forward), after a preliminary evaluation through EFA (exploratory) analyses performed under the assumption of maximum likelihood (a statistical method utilized to unveil the underlying structure of a relatively large set of items or variables) with Promax oblique rotations. The rotation method was chosen as it is most sensible to first examine the solutions produced by one or more of the common methods of oblique rotation, allowing researchers to refine their understanding of the data (Fabrigar et al., 1999). Also, and since it allows researchers to set factor loadings on the same scale, data was standardized (Brown, 2006; Kaplan, 2000), thus being possible to compare the size of the factor loadings to assess. Considering the appropriate outcomes of the EFA, that endorse the fundamental assumptions of the questionnaire, the present investigation employed confirmatory models.

This perspective comprised the "a priori" or baseline model to be compared. It is worth mentioning that CFA involves numerous benefits regarding the management of missing data, as well as of ordinal, categorical, and/or variables that are non-normally distributed (Finney & DiStefano, 2013; Useche, Cendales, et al., 2018). In addition, one relevant benefit of CFA is the possibility of determining which option (*i.e.*, proposed model) has the most appropriate and parsimonious fit, thus allowing the assessment of numerous models under diverse theoretical suppositions and conjectured constructions. The R-based *lavaan* "latent variable analysis" software (version 0.6–5) was used for specifying and estimating structural models.

As suggested in previous research, numerous estimators and coefficients from different types were used to weigh the model fit – see Marsh et al. (2004) for further information. These estimators were: Chi-square (χ^2), discrepancy ratio (χ^2/df); Root Mean Square Error of Approximation (RMSEA); Normed Fit Index (NFI), Tucket-Lewis Index (TLI), Confirmatory Fit Index (CFI). Goodness-of-fit cut-off points were established as proposed by Marsh et al. (2004): CFI/NFI indexes >0.90, an RMSEA <0.080, and a χ^2/df ratio < 5.0 suggest an adequate model fit.

Moreover, the suitability of the model was assessed as well, employing the strength and coherence of the estimates, in addition to the absence of great/redundant modification indexes (Ruiz-Hernández et al., 2020). Lastly, the internal consistency and reliability of the questionnaire and its items were estimated through (*i*) Cronbach's coefficients – α, and (*ii*) Composite Reliability Indexes (CRIs), an additional index based on the factor loadings and residuals found in the confirmatory outcomes. This indicator helps to overcome some of the traditional limitations of Cronbach's Alpha coefficients as a single way of determining the reliability (or not) of a questionnaire scale (Morera & Stokes, 2016; Raykov, 2001).

Finally, validity insights were assessed through (*i*) Rho (Spearman's) correlational analyses with literature-endorsed variables (convergent validity), and (*ii*) comparative analyses on the dimensional scores of the MCSS by gender, age group, and commuting modality (criterion validity). For this purpose, there were used Welch's comparative tests, a Student's t-based non-parametric statistical technique offering a considerable set of advantages over parametric tests such as ANOVA – particularly if variances are inequal and sample sizes are not necessarily proportional. IBM SPSS Statistics for Macintosh (Version 28.0; IBM Corp., Armonk, NY) was used to perform descriptive and comparative tests of this study.

2.6. Ethics

The Research Ethics Committee at the Research Institute on Traffic and Road Safety granted permission to perform this study and certified that it responded to the general ethical principles addressed in the Declaration of Helsinki, as required for the case of research using human subjects (IRB approval number HE0001250521).

The risk level of the study was determined as *very low* considering that no individual data besides standard demographics were gathered, the anonymity of the subjects was strictly maintained, and the current social distancing and bio-security protocols were properly followed, to guarantee the safety of both research staff members and study collaborators. All participants agreed to partake by signing the Informed Consent Form, containing information on the purpose, methods, and treatment of research data.

3. Results

3.1. The measurement model

With the aim of understanding the factorial structure of the Multimodal Commuting Stress Scale (MCSS), a sequentially structured measurement model was developed.

For this purpose and given that EFA suggested a reasonably adequate structure for the MCSS to a four-factor solution, with 68.91% of variance explained, and all item factor loadings – $\lambda s > 0.40$. As rotated solutions can be considered as interpretable and theoretically sensitive (Fabrigar et al., 1999; Kaplan, 2000) and the exploratory item distribution made theoretical sense, competitive CFA structural analyses were performed, finding that the original factor composition of the MCSS has an overall adequate set of goodness-of-fit indexes.

The competitive analysis considered three possible models: (*i*) a unifactorial solution, assuming all commuting stress-related issues within a single dimension, what a priori makes sense but could impair the discriminative value of a more specific multi-factorial structure; (*ii*) a raw (baseline) four-factor solution composed of the theoretically hypothesized dimensions appended in the literature review; and (*iii*) an adjusted (improved) four-factor structure, in consideration of variable and error covariances and large (and always theoretically parsimonious) modification indexes, based on the theoretical sensitiveness features proposed by Fabrigar (1999) in psychological and overall behavioral applied measurement.

The model fit for the unifactorial solution was considerably inadequate, while the baseline four-factor model showed a set of better

fit indexes, although they were slightly adjustable through a careful inspection of psychometric improvements. A close inspection of this unconstrained four-factor model allowed us to identify a reduced set of very large modification indexes that pointed out a relevant relationship between some items. The new simplified model fitted the data reasonably well, making qualitative sense and keeping adequate psychometric values, as shown in Table 2.

Subsequently, and since this measurement model initially endorsed the value and pertinence of each one of the four latent constructs included in the questionnaire (*AKA* factors or dimensions; see Fig. 1), a set of validity and reliability indicators was obtained, as shown in Table 3.

The validity, reliability, and consistency of the measures were tested through several key indexes: standardized factor loadings (λ coefficients), Composite Reliability Indexes (CRIs), and Cronbach's Alpha coefficients (α).

Overall, the factor loads (λ coefficients) presented by each one of the 21 items composing the questionnaire were considered adequate, since all of them were $\lambda > 0.610$, which added to the good fit of the model and contributed to discarding the need of deleting items presenting potential psychometric shortcomings.

3.2. Reliability measures

The Composite Reliability Indexes (CRIs) of all factors ranged between [0.979 and 0.990], being these very satisfying reliabilities for all the four latent constructs. CRI for F1 (*Inefficiency and inconvenience*) was 0.990; 0.981 for F2 (*Unsafety and insecurity*); for F3 (*Congestion and crowding*) CRI was 0.979; and 0.987 for F4 (*Psychophysical Strain*).

Moreover, Cronbach's Alpha coefficients (α) were all over $\alpha = 0.846$. In other words, Cronbach's Alpha estimates were all above the usual 0.700 criteria, as noted in methodological sources (for guidance, see "Data Analysis" section), that also suggest using Alpha coefficients as a complementary but not as a single reliability index (Morera & Stokes, 2016), which suggests adequate internal reliability: 0.911 for F1 – *Inefficiency and inconvenience*; 0.866 for F2 – *Unsafety and insecurity*; 846 for F3 – *Congestion and crowding*; and 0.913 for F4 – *Psychophysical Strain*.

3.3. Factor correlations and convergent validity

Overall, the four dimensions of the MCSS keep adequate coherent and significant associations, both (*i*) among pairs of them, with all *rho* bivariate correlations having a positive directionality, being statistically significant and of considerable magnitude, and (*ii*) with BMI and self-reported health-related variables. The whole set of correlations found between the MCSS main components (factors), and the criterion variables used can be seen in Table 4.

Some correlations worth noting are the significant associations between factors F1 (II), F2 (UI), F3 (CC), and F4 (PS) and the self-reported scores of mental health status (except for F1), physical health and the Body Mass Index (BMI), that are in all cases negative and significant.

Also, and as expectable (providing another set of coherent associations), daily commuting length was positively correlated to scores in all the four MCSS factors. Finally, the self-reported number of crashes suffered while commuting in the last five years was positively associated to scores on both Psychophysical Strain (PS) and Unsafety and Insecurity (UI), *i.e.*, commuters having suffered more crashes during these movements also report greater scores in such indexes.

3.4. Sex, age and commuting means-based differences

With the aim of comparing the MCSS of commuters from different genders (males/females), age segments (young people, adults, and aging adults), and preferred transport means (except for the category "others", which was excluded), Welch (*W*) comparative tests, *i.e.*, robust mean analyses, more appropriate than conventional parametric tests for this set of subsample sizes and distributions, were

Table 2
Competitive factor analysis: Goodness-of-fit indices and model adjustment.

Model	X^2	df[1]	*p*	CMIN/df[2]	RMSEA[3]	90% CI for RMSEA		CFI[4]	NFI[5]	TLI[6]	IFI[7]	
						Lower threshold	Upper threshold					
Unifactorial model	4978.519	189	<0.001	26.341	0.133	0.130	0.136	0.762	0.755	0.735	0.762	
Four-factor baseline model	3499.462	182	<0.001	19.228	0.113	0.110	0.116	0.835	0.828	0.810	0.835	
Four-factor final model (**retained**)	456.318	128	<0.001	3.565	0.042	0.038	0.047	0.984	0.978	0.973	0.984	

Notes: [1]df = Degrees of freedom; [2]CMIN/df = Disparity ratio between X^2 and df; [3]RMSEA = Root Mean Square Error of Approximation; [4]CFI = Confirmatory Fit Index; [5]NFI = Normed Fit Index; [6]Tucker-Lewis Index.

Table 3
Item content, factor that the item belongs to, standardized factor loading (λ), standard error (S.E.) and p-values in the retained model.

#	Item Content	Factor	Descriptive statistics		Standardized factor loadings[3]		C.R.[6]	Sig.[7]	Reliability measures	
			Mean[1]	SD[2]	λ[4]	SE[5]			CRI[8]	Cronbach's Alpha
MCSS1	The time it takes me to make these trips is longer than it should be.	F1: Inefficiency and inconvenience	2.100	1.385	0.724	0.046	25.261	***	0.990	0.911
MCSS2	The cost of the means of transport I use is/are, in my perspective, high.		2.020	1.342	0.619	0.034	25.261	***		
MCSS3	Commuting travel times make me get up earlier/go to bed later than I should.		2.290	1.413	0.737	0.032	32.628	***		
MCSS4	The time I use in daily transportation makes it difficult to spend time with my family/loved ones.		1.790	1.442	0.776	0.043	25.612	***		
MCSS5	Transport delays have often made me late for work/study.		1.930	1.381	0.810	0.042	26.313	***		
MCSS6	I have been late for appointments or personal meetings after work/study, because of inefficient or delayed transportation.		2.040	1.395	0.804	0.042	26.348	***		
MCSS7	The transport means I use for these trips is/are uncomfortable.		1.670	1.339	0.875	0.046	23.718	***		
MCSS8	I frequently experience crash risks or conflicts with other users/vehicles while commuting.	F2: Unsafety and insecurity	1.720	1.302	0.645	0.036	24.368	***	0.981	0.866
MCSS9	I am often affected by traffic jams or congestion while traveling to/from there.		1.960	1.395	0.675	0.046	24.368	***		
MCSS10	I frequently witness criminal acts, harassment, or assaults while commuting.		1.240	1.236	0.670	0.044	19.402	***		
MCSS11	When I travel to/from there, I feel vulnerable to being robbed by other people.		1.560	1.363	0.824	0.058	2.109	***		
MCSS12	I feel vulnerable to being harassed by other people (e.g., words, looks, groping…) during my commuting trips.		1.460	1.337	0.800	0.059	19.874	***		
MCSS13	There is a lot of noise, pollution, or congestion in the mode of transportation I use on a daily basis.	F3: Congestion and crowding	1.870	1.378	0.720	0.050	24.729	***	0.979	0.846
MCSS14	I sometimes find it difficult to get my most commonly used means of transportation (e.g., low frequency, long lines, being crowded, not stopping).		1.810	1.389	0.770	0.034	31.414	***		
MCSS15	The traffic lights in my city do not help speed up traffic, and I often spend a long time waiting at them.		1.830	1.307	0.642	0.036	22.956	***		
MCSS16	There is no means of transportation that allows me to make these trips in a sufficiently agile and fast manner.		1.790	1.355	0.674	0.041	23.871	***		
MCSS17	Physically, I feel a bit tense while making these trips.	F4: Psychophysical Strain	1.690	1.386	0.800	0.043	23.667	***	0.987	0.913
MCSS18	At the end of my trips to/from there, I feel physically exhausted.		1.720	1.379	0.842	0.038	27.218	***		
MCSS19	At the end of my commute to/from there, I feel mentally exhausted.		1.720	1.375	0.863	0.040	27.887	***		
MCSS20	The weather conditions in my city make commuting physically or emotionally difficult for me.		1.630	1.337	0.700	0.039	23.302	***		
MCSS21	Whenever I experience mobility constraints while commuting, I feel uncomfortable or anxious.		1.880	1.374	0.744	0.041	23.667	***		

Notes: [1]Arithmetic mean; [2]SD = Standard Deviation; [3]All $p < .001$; [4]Factor loading; [5]SE = Standard Error; [6]CR = Critical Ratio; [7]Statistical significance (all p-values were < 0.001); [8]CRI = Composite Reliability Index.

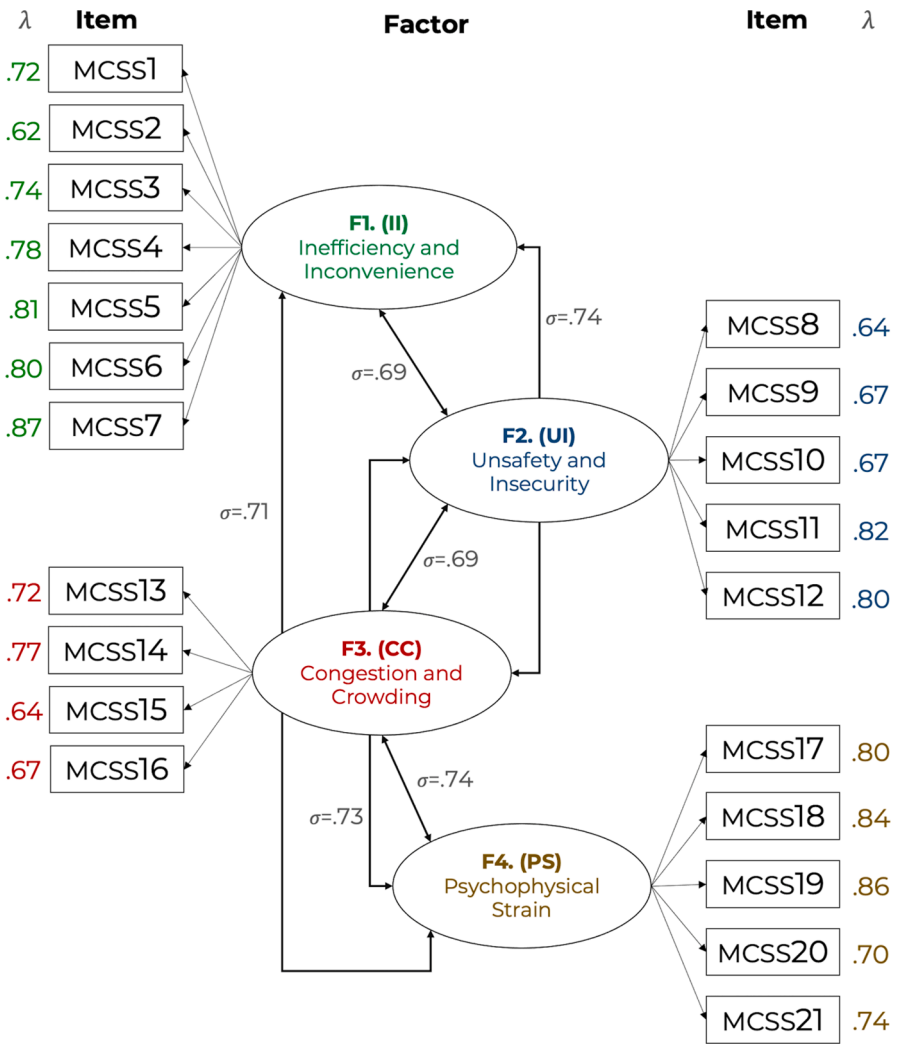

Fig. 1. Standardized parameter estimates and factor correlations. *Note:* All standardized estimates were $p < .001$; the numbers within squares represent the original numbers of the items in the MCSS (as shown in Table 3).

Table 4
Non-parametric correlations (Spearman *Rho*'s) between study factors and criterion variables.

Variable		M	SD	F2	F3	F4	CV[a]	CV[b]	CV[c]	CV[d]	CV[e]
F1	Inefficiency and Inconvenience (II)	1.80	1.03	0.690**	0.739**	0.707**	0.346**	−0.096**	−0.051	−0.064*	0.044
F2	Unsafety and Insecurity (UI)	1.23	0.87	–	0.687**	0.728**	0.170**	-0.086**	−0.059*	−0.057*	0.072**
F3	Congestion and Crowding (CC)	1.57	1.01		–	0.741**	0.175**	−0.095**	−0.078**	−0.064*	0.048
F4	Psychophysical Strain (PS)	1.35	1.00			–	0.234**	−0.131**	−0.080**	−0.078**	0.055*
CV[a]	Daily Commuting Length (min)	59.49	43.18				–	−0.074**	0.005	−0.018	0.021
CV[b]	Self−rated Mental Health (0–10)	7.61	1.73					–	0.381**	0.070**	−0.042
CV[c]	Self−rated Physical Health (0–10)	7.00	1.55						–	−0.144**	−0.001
CV[d]	Body Mass Index (BMI)	24.18	5.33							–	0.014
CV[e]	Commuting crashes (5 years)	0.16	0.57								–

Notes: [a,b,c,d,e] Introduced as a criterion variable (CV). ** The correlation is significant at the $p < .01$ level (2-tailed). * The correlation is significant at the $p < .05$ level (2-tailed).

performed, unveiling significant differences among them, as shown in Table 5 (full set of comparative analyses) and briefly described below:

3.4.1. Gender differences

Overall, females reported significantly greater scores on all commuting stress factors (II, UI, CC, and PS) than male commuters, being the highest mean difference reported for UI – *Unsafety and Insecurity* ($M_{Diff} = 0.25$; Welch's $t = 28.13$; $p < .001$), and the lowest the reported for II – *Inefficiency and Inconvenience* ($M_{Diff} = 0.23$; Welch's $t = 17.53$; $p < .001$). These differences are graphically

Table 5
Descriptive data and Welch's robust mean comparisons for the 4 factors of the MCSS. Categorical factors: Gender, age group, and most frequent commuting means.

MCSS factor	Category	Group (Value)	Mean	Z[1]	SD	95% CI for Mean[2]		Mean differences (Robust Tests)		
						Lower	Upper	Welch	df[3]	p
F1: Inefficiency and Inconvenience	Gender	Female	1.90	0.10	1.03	1.83	1.97	17.532	1,1266.989	< 0.001
		Male	1.67	−0.13	1.02	1.58	1.75			
	Age[4]	Young adults	1.90	0.09	0.97	1.82	1.97	7.169	2,676.768	< 0.001
		Adults	1.77	−0.03	1.09	1.67	1.87			
		Aging adults	1.62	−0.17	1.08	1.49	1.75			
	Commuting means	Bus	2.17	0.35	0.97	2.04	2.29	21.453	6,23.166	< 0.001
		Metro or tram	2.07	0.26	0.92	1.96	2.18			
		Taxi or VTC	1.75	−0.05	1.13	0.99	2.51			
		Private car	1.74	−0.06	1.02	1.64	1.83			
		Motorized two-wheeler	1.57	−0.23	0.94	1.28	1.86			
		Non-motorized two-wheeler	1.46	−0.34	0.92	1.17	1.74			
		Walking	1.39	−0.40	1.04	1.26	1.52			
F2: Unsafety and insecurity	Gender	Female	1.34	0.12	0.90	1.27	1.40	28.135	1,1313.139	< 0.001
		Male	1.09	−0.16	0.81	1.02	1.15			
	Age[4]	Young adults	1.22	−0.01	0.81	1.16	1.28	1.324	2,664.438	0.223
		Adults	1.28	0.06	0.90	1.19	1.36			
		Aging adults	1.17	−0.07	0.96	1.05	1.28			
	Commuting means	Bus	1.39	0.18	0.87	1.27	1.50	3.697	6,229,269	< 0.010
		Metro or tram	1.28	0.06	0.78	1.19	1.37			
		Taxi or VTC	1.52	0.34	1.21	0.71	2.34			
		Private car	1.23	0.00	0.86	1.15	1.31			
		Motorized two-wheeler	1.20	−0.03	0.83	0.95	1.46			
		Non-motorized two-wheeler	1.02	−0.24	0.85	0.76	1.26			
		Walking	1.07	−0.18	0.91	0.96	1.19			
F3: Congestion and Crowding	Gender	Female	1.67	0.10	1.04	1.60	1.74	18.955	1,1308.198	< 0.001
		Male	1.43	−0.13	0.95	1.36	1.51			
	Age[4]	Young adults	1.64	0.07	0.92	1.57	1.71	2.919	2,663.505	0.054
		Adults	1.53	−0.05	1.06	1.43	1.63			
		Aging adults	1.48	−0.08	1.09	1.35	1.61			
	Commuting means	Bus	1.93	0.36	0.99	1.81	2,06	13.726	6,229.928	< 0.001
		Metro or tram	1.76	0.19	0.85	1.66	1.86			
		Taxi or VTC	1.72	0.15	1.24	0.89	2.56			
		Private car	1.40	−0.17	1.00	1.31	1,49			
		Motorized two-wheeler	1.54	−0.03	0.83	1.26	1.82			
		Non-motorized two-wheeler	1.36	−0.21	0.95	1.08	1.64			
		Walking	1.39	−0.18	1.08	1.26	1.52			
F4: Physical Strain	Gender	Female	1.46	0.11	1.03	1.38	1.53	21.560	1,1310.869	< 0.001
		Male	1.20	−0.14	0.94	1.13	1.28			
	Age[4]	Young adults	1.39	0.03	0.98	1.31	1.46	2.163	2,686.653	0.106
		Adults	1.37	0.02	1.02	1.27	1.46			
		Aging adults	1.23	−0.11	1.03	1.11	1.36			
	Commuting means	Bus	1.67	0.31	1.04	1.53	1.80	12.400	6,231.420	< 0.001
		Metro or tram	1.56	0.20	0.93	1.45	1.67			
		Taxi or VTC	1.65	0.30	1.30	0.78	2.52			
		Private car	1.23	−0.12	0.98	1.14	1.32			
		Motorized two-wheeler	1.17	−0.18	0.76	0.90	1.44			
		Non-motorized two-wheeler	1.26	−0.09	0.89	1.00	1.52			
		Walking	1.09	−0.26	0.99	0.97	1.21			

Notes: [1]Z = Standardized Score; [2]CI = 95% Confidence Interval for the Mean; [3]df = Degrees of freedom; [4]Disproportional groups were weighted for the comparative analyses.

presented in Fig. 2.

3.4.2. Age group differences

Inter-group differences were significant for all four MCSS factors (see right column of Table 4 for test coefficients). Addressing the specific age groups, young adults reported the greatest mean values for three out of the four factors (II, CC, and PS) of the MCSS. Even though, significantly greater values of UI were found among adults between 26 and 50 years, in comparison with both younger and older commuters.

On the other hand, aging adults (commuters over 50 years) reported lesser means for all the four commuting stress dimensions measured by the MCSS (significant at the level p <.050). The whole set of age group-based trends in the four MCSS factors are graphically presented in Fig. 3.

3.4.3. Commuting mode differences

The greatest mean values for II, CC, UI and PS were found among commuters performing their usual movements by public buses, while the lesser scores in II and PS were found among walking commuters.

On the other hand, the lowest mean scores for CC and UI were found among non-motorized two-wheeler commuters. Considering the great number of categories existing for this factor and with the aim of portraying the commuting mean-based trends of the MCSS scores, this data is also graphically presented in Fig. 4, using the Z scores appended in the fifth column of Table 5.

4. Discussion

The core aim of this empirical research was to thoroughly present in detail the development and validation of the Multimodal Commuting Stress Scale (MCSS). In this regard, this study confirmed that the MCSS has a reasonably good dimensional structure guaranteeing its psychometric value and reliability for measuring commuting stress in a multidimensional perspective, with both factor and item contents applying to commuters of different means, moving under diverse trip conditions.

4.1. Psychometric strengths and indexes of the MCSS

Psychometrically speaking, and beyond from high alpha coefficients (all above 0.800) and CRI (all above 0.940) indexes, plus items with high factorial weights (all $\lambda > 0.600$), the questionnaire was satisfactorily adjusted to a parsimonious structure consisting of a four-dimensional latent variable model, with the following factors: *Inefficiency and Inconvenience (F1), Unsafety and Insecurity (F2)*; *Congestion and Crowding (F3)*; and *Psychophysical Strain (F4)*. These labels respond, in the first place, to the content of the items with greater factorial weight for each dimension and, secondly, to the shared theoretical background of the MCSS regarding other previous evidences based on commuting stress research advances from different urban locations (Hansson, Mattisson, Björk, Östergren, & Jakobsson, 2011; Koslowsky, 1997; Kumagai, Wakamatsu, & Managi, 2021; Wang, Rodríguez, Sarmiento, & Guaje, 2019), which use both self-report, observational and objective data' analysis-based approaches for assessing different situations potentially enhancing its occurrence among urban commuters (Chatterjee et al., 2020; Wang et al., 2019; Legrain, Eluru & El-Geneidy, 2015; Ursin & Eriksen, 2004).

This psychometric finding, *i.e.*, the four-dimensionality plausibleness of the questionnaire, acquires theoretical relevance since it supports the ability of the instrument to differentiate between them from the exploratory to the confirmatory phases of the analysis

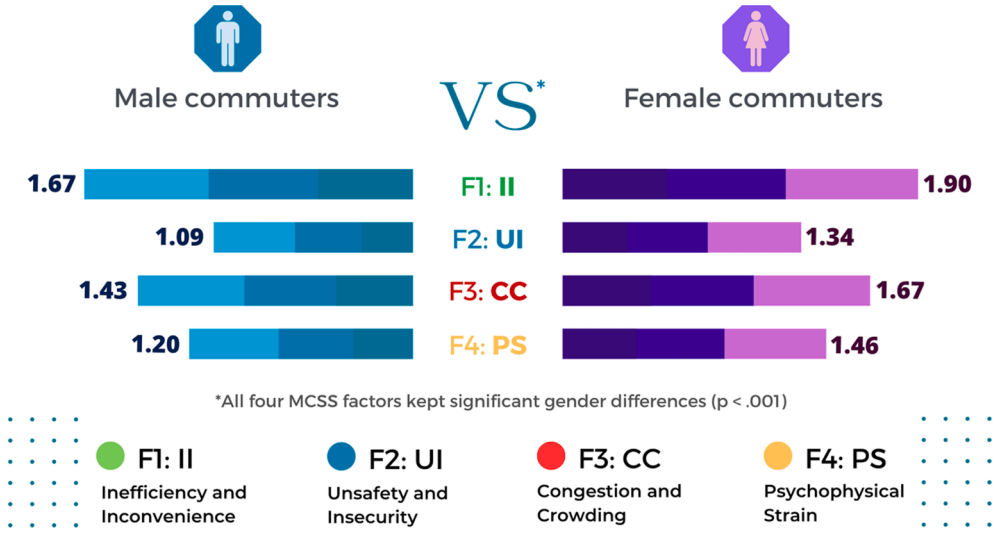

Fig. 2. MCSS factor mean values between male (n = 615) and female (n = 814) commuters.

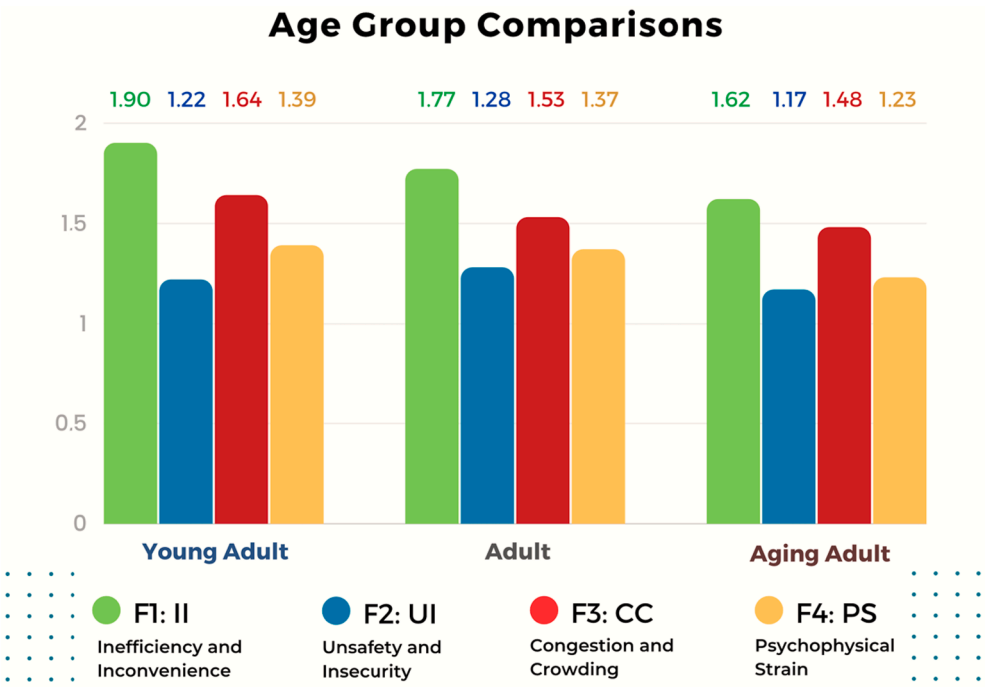

Fig. 3. MCSS dimensional values according to age group: young adult (n = 674), adult (n = 450), and aging adult (n = 305) commuters.

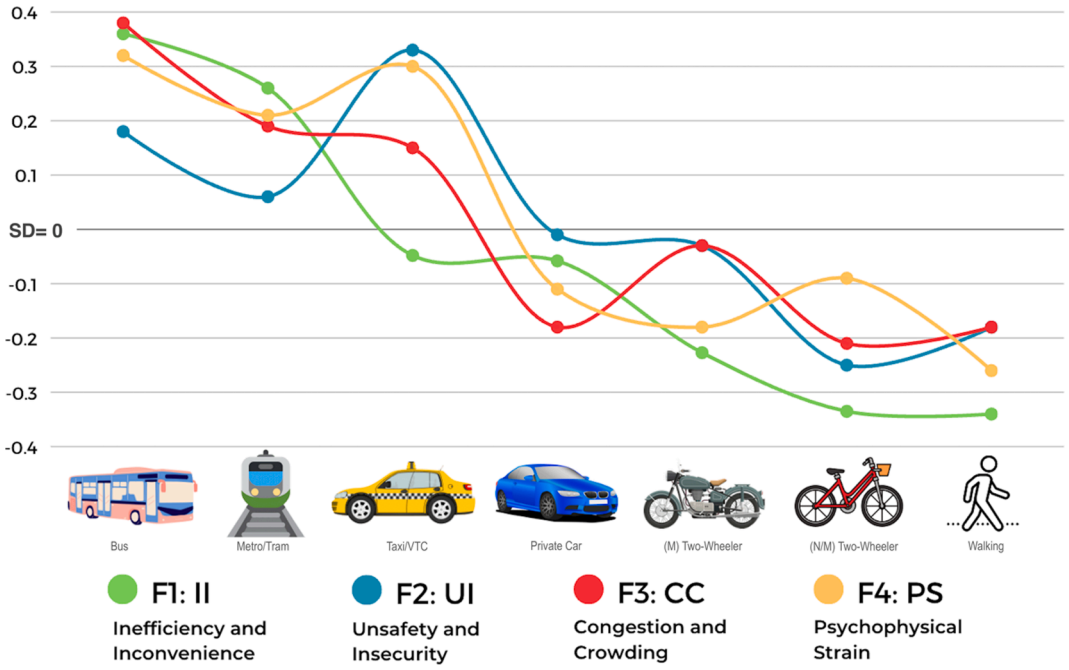

Fig. 4. MCSS factor mean values among different commuting modalities (n = 1,429). *Notes:* Axis *Y* (left column) is graphically scaled in terms of standardized (Z) scores to favor fair comparability.

process. This differentiation between key spheres – especially among (on the one hand) environmental conditions, possible infrastructural shortcomings and their safety and security dynamics, and (on the other) the subjective stress-related appraisals is crucial when considering that the evidence shows how individual and transport means-related factors may modulate commuting stress-related experiences, outcomes and differences (Hansson, Mattisson, Björk, Östergren, & Jakobsson, 2011; Legrain, Eluru, & El-Geneidy, 2015; Roberts, Hodgson, & Dolan, 2011; Schäfer et al., 2020).

As a technical matter, however, it should be noted that for inferential tests implying directional assumptions (e.g., regression or prediction models), *Psychophysical strain* (F4) should not be placed at the same level as factors 1 to 3, since -in correspondence with the existing theoretical and empirical evidence- strain is assumed to be an outcome partially explained by the other three scales composing the MCSS.

4.2. Demographic and commuting mode-based differences

As stress-related research is nowadays based on the assumption that it is modulated by the interactions between individual and environmental factors, one of the most relevant features of a self-report questionnaire aimed at assessing it should be its ability to find differences between individuals if –as most frequently seen in social research– demographic and behavioral differences are considered (Epel et al., 2018; Fabrigar et al., 1999; Useche et al., 2019).

For this purpose, and grounded on the assumption that sociodemographic factors such as age and gender might affect commuting stress-related issues (Diebig et al., 2021; Kumagai et al., 2021), three literature-based variables (*i.e.*, gender, age group, and commuting modality) were hypothesized to act as differentiating factors for commuting stress. In this regard, the statistical analysis results seem to support both the criterion and external (convergent) validity of the Multimodal Commuting Stress Scale in the light of previous empirical insights.

4.2.1. Gender and age

In a preceding study, Roberts, Hodgson & Dolan (2011) found that, overall, females tended to be higher CS scorers than males. This allowed them to suggest that same as with many other transport problems, commuting stress issues might be considerably "gendered". Consistently, the current study found that these differences occur in all four MCSS factors, and female commuters remain more prone to report greater commuting stress rates. In a similar way, other previous empirical experiences have highlighted the need of considering gender as a key factor to explain differences in terms of both road behaviors and commuting stress experiences, since the differential degree and quality of stressors usually faced by urban commuters –and therefore the outcomes in these regards– could differentially work to a substantial extend between male and female commuters (Ceccato & Loukaitou-Sideris, 2021; Hansson et al., 2011; Roberts, Hodgson & Dolan, 2011; Useche, Hezaveh, Llamazares & Cherry, 2021). All in sum, the outcomes of this extensive sampling procedure with the MCSS support these assumptions.

Secondly, and as for age differences, the outcomes of this study show coherence with previous literature in regard to the association between age and commuting stress. Prior studies such as Mattison (2016) and Talbot et al. (2016) have addressed significant differences in terms of commuting stress appraisals among commuters of different age groups. Overall, and in the same line as the current study, this association tends to be negative and younger commuters remain a key group to address in commuter stress-alleviating actions and interventions.

However, it is worth saying that these results cannot be linearly understood, as they remain prone to many confounders and specificities. For instance, studies addressing the case of aging commuters have also found particular stress-related threats for this age segment, whose nature differs from the typical impedance problems commonly referred to by younger commuters (Jin et al., 2022; Talbot et al., 2016).

4.2.2. Commuting modality differences

Another key criterion validity-related issue necessary to test was the *multimodal* character of the MCSS, *i.e.*, its capability to differentiate commuting stress-related factors and outcomes across different commuting modalities. This can be discussed in light of two facts: firstly, the literature background and, secondly, the specific outcomes of the statistical analysis.

In regard to the first, and even though empirical sources remain substantially limited, most existing studies consistently state both driving commuting and massive transportation systems as those involving more potential stressors, in addition to potentially unexpected situations and convenience issues increasing commuting stress likelihood (Cendales et al., 2023; Legrain et al., 2015). On the other hand, it is coherently supported that more active commuters would be those reporting comparatively lesser commuting stress rates (Evans & Wener, 2006; Kumagai et al., 2021; Saunders et al., 2013; Wener & Evans, 2011).

As for the second (*i.e.*, statistical analysis outcomes), the results of this study endorse the aforementioned literature-based assumption, since both walking and non-motorized two-wheeler commuters had comparatively and significantly lesser commuting stress scores in all MCSS factors than other groups of them commuting by bus, metro/tram, and four-wheeled vehicles, as shown in Fig. 4.

Indeed, the only relevant difference with the literature was that some previous studies have assumed driving as the most stressful commuting mode (Legrain et al., 2015), while in our study massive transportation was found to be at the top of this 'commuter stress ranking'. However, it is worth mentioning that further studies do actually support the idea that CS can be greater in other means different to private car using, giving recurrent constraints such as excessive trip length, system inefficiency and vehicle crowding (Halonen et al., 2020; Kim et al., 2019; Mattison, 2016; Rezapour & Richard Ferraro, 2021).

4.2.3. Other validity insights

Apart from the aforementioned literature-based comparisons, the MCSS has shown plausible convergent validity insights when crossing its four dimensions with third variables that are theoretically related to mental and physical health, and the commuting safety indicator used in this study (*i.e.*, commuting crashes suffered in the last five years).

Namely, the four MCSS dimensions kept reasonable test significance and coherent directions to these criterion variables (*i.e.*) all

health-related indexes, including both BMI and self-rated physical and health measures (Halonen et al., 2020; Gottholmseder et al., 2009), and the previously documented relationship between trip-related variables such as commuting time and the commuting stress scores in various stress and wellbeing-related dimensions, as endorsed by previous studies made with urban commuters (Clark, Chatterjee, Martin & Davis, 2020; Mattison, 2016; Mattisson, Jakobsson, Håkansson & Cromley, 2016).

Finally, the results of this study also highlight the need of considering the "flip-side of the coin" of an eventual over-encouraging of massive transportation in absence of consideration for commuters' stress outcomes. While it does not imply that public transport using is 'harmful to health', there is (same as in any other means) a set of stress-related issues needing action to improve commuters' trip experiences and outcomes, especially at urban locations (Clark, Chatterjee, Martin, & Davis, 2020; Ding, Gebel, Phongsavan, Bauman, & Merom, 2014; Evans & Wener, 2006; Kumagai, Wakamatsu, & Managi, 2021; Macassa et al., 2018). Moreover, policies aimed at improving the mobility of great segments of the daily commuting population (e.g., workforce and students) should consider the psychological experience of urban trips as a relevant part of their further health outcomes (Calderwood & Mitropoulos, 2021).

5. Conclusions

This paper aimed to present the development and validation process of the Multimodal Commuting Stress Scale (MCSS). Its key conclusions are presented below:

Firstly, in psychometric terms, the scale was found to have a suitable set of factor loadings, reliability and consistency indexes, and to fit well into a theoretically-based four-factor structure.

Also, commuting stress factors measured through the MCSS have shown coherent and significant associations with commuters' both physical and mental health indexes, trip-related factors, and safety outcomes.

Finally, comparative analyses show interesting differences in all the MCSS dimensions when compared by gender, age, and commuting modalities, endorsing its criterion validity and potential to make inter-group comparisons of commuting stress-related factors.

6. Limitations of the study and further research

As we have systematically described throughout the paper, the present research was funded on both a theoretical and empirical basis, using the evidence retrieved from a substantially large sample of Spanish commuters. All the information was watchfully collected, processed, and examined considering the most appropriate statistical procedures and parameters for each one of the analyses presented.

However, this study has a set of core limitations that should be considered when interpreting its outcomes:

Compared to objective studies, self-report designs imply an increased likelihood of certain biases affecting their outcomes. First of all, the data can be considered prone to common method biases (CMBs) related to social desirability and memory flaws, given that the questionnaire inquiries about both public behavior and daily commuting information that could be properly recovered (or not) during the answering phase.

Secondly, the comparative value of this questionnaire is limited in some specific cases. While items are generic and applicable to all conventional commuting modes, it could be certainly difficult to conduct such comparisons among groups of users simultaneously combining diverse commuting modes, given both the combinatory logic of this issue and the difficulty to determine specific stress-related patterns. For these specific purposes, methodological literature typically advises for conducting mixed-method approaches, *i.e.*, adding qualitative techniques to the information provided by a psychometrically interpretable scale (Bergin, 2018; Creamer, 2017).

Thirdly, the subsamples were considerably small to make reliable inferences in regard to commuting stress in specific transport means; in other words, although robust analyses allow for making reliable comparisons, further inferences should be funded on in-depth analyses, for which this self-report questionnaire is valuable but could (still) be well complemented by other types of complementary measures and methodologies useful to assess stress-related factors in commuting contexts (e.g., real-time monitoring with biofeedback devices, controlled and naturalistic observations).

CRediT authorship contribution statement

Sergio A. Useche: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Software, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing. **Cristina Marin:** Conceptualization, Data curation, Funding acquisition, Supervision, Validation, Visualization. **Francisco J. Llamazares:** Conceptualization, Project administration, Funding acquisition, Resources, Validation, Software.

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.

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