

Exploring user experience of transport modes through the multiple dimensions of psychological comfort

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Abstract

The notion of user experience in HCI and other domains includes the emotional experience beyond instrumental aspects such as usability, usefulness or price. In the transport sector, a passenger-centric approach that integrates a focus on user experience has similarly emerged with a view to guiding and enriching design. Adopting this approach, we surveyed 502 frequent commuters evaluate 24 previously identified sources of psychological Comfort/Discomfort [1] [2] across eight modes of transport, with the goal of identifying their specificity in terms of passengers' experience. Dimensions such as social norms and social representations associated appear overwhelmingly considered to be of little importance, while expectations regarding an instrumental dimension like Time control, Accessibility and Safety remain high overall, alongside other dimensions specific to the various modes. In particular, we identified a set of 16 sources from broad categories like Social Interaction, Space, aesthetics and Sensory Ambiances, Safety feeling, Control, Multiple activity and Attention load, as dimensions of psychological comfort experienced by commuters in relation to the transport modes they use. These dimensions could offer pathways into how to improve public transport systems and infrastructure for soft modes, by indicating the sources of discomfort and comfort, and how to encourage modal shift from private car to shared or soft modes. We conclude on limits and perspectives.

CCS Concepts

• **Social and professional topics** → User characteristics;

Keywords

Psychological comfort, user experience, public transports, mobility shift

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1 INTRODUCTION

In HCI and other domains, the notion of user experience includes the emotional experience associated with using a system, tool or service [3] [4], beyond instrumental aspects such as usability, usefulness or price. Similarly, in the transport sector, a passenger-centred approach has emerged that integrates a focus on user experience to guide and enrich design [5] [6] [1] [7]. Studies dealing with user characteristics have mostly focused on the acceptability of transportation modes, determinant of mode choice, and passenger's satisfaction with a focus on instrumental or pragmatic dimensions, such as the price, the duration of the trip and the availability of the mode; in parallel, there is a strong line of research on (mostly) physical comfort related to seating, temperature and vibrations in the domains of air travel and automobile design (cf [8], for passengers comfort review; [9]). The notion of comfort has been extended to encompass psychological and subjective dimensions beyond the physical, physiological and biomechanical dimensions of passengers' activity [10] [11] [12] [13]. Recently, approaches of the passengers' satisfaction have been developed [5] [6] [7], including the notion of psychological comfort and the numerous factors influencing it during the use of transport modes. Psychological (or emotional) comfort/discomfort was defined by [14] "as a global feeling which is dynamically constructed through the affective states lived by a user. (...) He uses the tools we design for him with his rational way of thinking but also with his sensible way of feeling. The comfort/discomfort is an affective phenomenon, involving together the body and the mind, but it can have a cognitive or a socio-relational origin, and it is essential to put into light these sources of discomfort in the situated use". Investigating the different dimensions of psychological (or emotional) comfort experienced by the user should provide an avenue for specifying and improving the design of transport systems, and could also be used to better support the shift towards low-carbon transport modes and greener choices.

In this study, we investigated how frequent users evaluate previously identified sources of psychological Comfort/Discomfort [1] [2] across eight modes of transport, with the aim of examining their specificity in terms of passenger experience. To this end, we designed and administered a questionnaire to a sample of 502 users of public and private modes in the Paris region (Ile de France), and analyzed the importance and frequency of exposure to these sources for the most commonly used modes of transport. The results reveal different facets of the user experience and its contingency, suggesting different avenues for design and public action related to the transition to low-carbon mobility.

Table 1: Sample characteristics

	Male	Female	Has a driving licence	Has a car	Total
<i>Localization</i>					
Paris	62	41	85	64	103
cities > 100.000 inhabitants	11	5	12	11	16
20.000 – 100.000 inhabitants	115	154	217	212	269
2.000-20.000 inhabitants	45	55	86	89	100
<2.000 inhabitants	9	5	13	13	14
<i>Age</i>					
18-24 y.o	31	36	38	42	67
25-39 y.o	72	99	144	137	172
40-54 y.o.	76	76	127	118	152
55-70 y.o.	63	49	103	92	111
Total	242	260	413	389	502

Table 2: Distribution of modes mainly used in the sample

Modes	Amongst the three main modes actually used (% of the whole sample)	Male/Female distribution between users	Declared as the first most used mode	Declared as the second most used mode	Declared as the third most used mode	Declared as avoided
Private car	219 (44%)	44%-56%	143	45	31	22
Metro	210 (42%)	54%-46%	86	89	35	44
RER /Suburban train	193 (39%)	51%-49%	119	41	33	77
Bus	190 (38%)	40%-60%	71	78	41	84
Walking > 10 minutes	141 (28%)	49%-51%	50	50	41	5
Tramway	53 (11%)	60%-40%	7	20	26	25
Bike and station-based bike sharing	31 (6%)	71%-29%	14	7	10	78
TER/ Intercity train/ mainline train	19 (4%)	37%-63%	7	6	6	38
Carpooling	11 (2%)	36%-64%	-	6	5	66
Motorcycles	9 (2%)	67%-33%	4	4	1	75
Taxi and private-hire drivers	6 (1%)	33%-66%	-	3	3	78
Car sharing	3 (1%)	33%-66%	-	1	2	63

2 METHOD

2.1 Participants

502 adults (242 men, 260 women) aged between 18 and 70 years ($m = 42$, $sd = 14$), representative of public transport users in Ile-de-France (Paris and suburbs) were recruited by the BVA group in their online panels (see Table 1). The Ile de France region is characterised by its accessibility to a wide range of public transport services, making it possible to make comparisons between different modes of transport. More than two thirds of the participants are couples and about 46% of them have one or more children living with them. Most had a driving licence (82%) and access to a car (78%), although this was lower among younger people. Trips of

15-30 minutes were the most common, followed by 30-45 minutes and 45-60 minutes.

On average, respondents reported using 2.6 different main modes of transport (see Table 2 for a detailed distribution of modes). The private car was the most frequently used mode, closely followed by the metro, urban trains (RER, a type of suburban metro, or other suburban trains), buses and walking. The other modes were much less frequently reported by respondents. Private cars and RER/suburban trains appear more frequently as the first mode, while metro and bus appear more frequently as the second mode. Forty-five percent of respondents (225/502) indicated that they avoid some modes of transport whenever possible. Buses, bicycles, taxis, RER and motorcycles/scooters were most frequently avoided.

2.2 The Comfort/Discomfort (C/D) Questionnaire

We designed a questionnaire to assess the perception of sources of comfort/discomfort in mobility situations associated to transport modes, based on a review of the literature on comfort and passenger experience of users of different transport modes [1] and further in-depth qualitative research [2]. This research previously identified 7 main categories of sources of comfort/discomfort, comprising between 2 and 7 sub-dimensions (Table 3). Each subdimension was assessed through an item that describes a specific transport situation and the experience and feeling related to this subdimension of comfort. As an illustration, the subdimension of Personal values associated to the context of using a suburban train was represented by the item “I sometimes think that I feel more in tune with my ideas and principles when I use the RER/Suburban train”. All (but one, i.e. the item about “attentional overload” situation) items were positively formulated, that is all the depicted situations were comfort situations. We obtained a set of 24 items (cf. Table 3) that was then adapted to fit with 13 specific transport modes existing in the area (see Table 4). Items related to “aesthetics of the interior environment” and “Sensory ambiances - temperature” were not used in the 4 modes for which they were non applicable or irrelevant, namely “motorcycle/scooter”, “bike”, “bike sharing” and “walking”. Subsequently, all but these 4 modes had 24 items whereas the former used only 22 items.

Each item was assessed first in terms of how frequent the user experienced the situation and then in terms of how important the user perceived it. The perceived frequency of the situation was measured by a 4-point Likert-like scale from 1 to 4 (never/seldom/frequently/very frequently). The perceived importance of the Comfort situation was similarly measured using a 4-point Likert-like scale from 1 to 4 (not at all important/not very important/somewhat important/very important). A pilot test of the survey was conducted to determine the intelligibility of the items, that led to slightly rewording few items. The (C/D) scale was tested as reliable for the two most represented modes “car” ($n=219$) and “RER/Suburban” ($n=193$) (respect. Cronbach’s $\alpha = 0.939$ and 0.923).

2.3 Procedure

The online survey has three parts: (1) questions about the socio-demographic profile of the respondents (age, gender, occupation, family situation, composition of the household, place of residence), their travel habits, preference and the characteristics of their mobility environment (Driving licence, preferred modes used for commuting, accessible and available modes at home and at work, existence of intra- and intermodal transfers on these journeys, modes not used intentionally); (2) the Comfort/Discomfort questionnaire. To limit the time required for the study, participants were asked to rate the frequency and importance of C/D sources for the 3 modes they used most often. Participants were given the instruction: “You are presented with situations on the use of the 3 means of transportation that you reported using most often. For each of these situations, we ask you to indicate with the help of a scale: (a) If this situation happened to you more or less frequently, from “never” to “very frequently”, (b) If you consider that it is an important element for you in relation to the comfort/ discomfort that this mode of

transport provides you with, from “not at all important” to “very important”; (3) questions (not used in this article) about carpooling practices. Participants took about 40 minutes to complete the survey.

2.4 Analysis

Three modes were not further considered (carpooling; motorcycle; taxi and private-hire drivers) and we grouped the responses for bike and bike sharing, due to the low number of participants for these modes. For each mode and each source, we computed the proportion of participants who rated it respectively as important and as frequent. This was done by summing respectively the number of participants that responded “somewhat important/very important” and that responded “frequently/very frequently” divided by the total number of respondents for each item. These enable us to evaluate for each mode, the perceived importance of comfort/discomfort sources and the frequency of exposure to these sources by the participants (see Figure 1 illustrating our approach for private car). Indeed, the higher the proportion of participants who consider the sources important, the greater the importance attributed to the source by the users. The reasoning is similar for the assessment of frequency: the higher the proportion of participants who consider the exposure to the source to be frequent, the more frequent this exposure is perceived. Since the statements in the items are systematically ‘positive’, i.e. described as a situation of comfort, it follows that a high rating of the frequency of exposure can be interpreted as a general assessment of the level of comfort for the source in question. Conversely, a low frequency of exposure will be interpreted in terms of perceived discomfort associated with the source. The Comfort dimension of the sole negative item (“attentional overload”) was scored in a reverse fashion. We also calculated the median proportion of participants who rated all sources as important and as frequent.

3 RESULTS

3.1 A big picture about importance and frequency of psychological comfort sources across eight most used transport modes

3.1.1 Importance of comfort sources. To facilitate a comparative overview across eight most used transport modes in our sample, we reported the most and the least important comfort sources in Table 4. Whatever the mode, median values for the perceived importance of investigated sources are higher than .50, that is more than 50% of their users perceived most of the comfort sources as “somewhat important” or “very important”. An explanation can be that the modes used most by users are, at the same time, those that maximise the comfort sources for them. This confirms also the relevance of the multiple sources across the investigated modes. Importance of comfort sources was scored higher for private car followed by the RER/suburban train, bus and cycle and station-based bike sharing. Lowest comfort sources importance values are associated to the tramway and transport-related walking. The importance attributed by users to the various sources of comfort reveal some similarities and differences depending the modes. “Social Image” exhibits the lowest importance scores across all comfort sources for 5/8 modes

Table 3: Categories of sources of comfort/discomfort and their sub-dimensions; examples of items used in the questionnaire for the importance and perceived frequency rating scales in the context of the "RER and suburban train"

Source of comfort/discomfort	sub-dimension(s)	Corresponding items adapted to RER/Suburban train experience
Personal values and social image adequacy	<i>Personal values</i>	I sometimes think that I feel more in tune with my ideas and principles when I use the RER/Suburban train
	<i>Social image</i>	I sometimes think that by using the RER/Suburban train I am sending a positive image of myself to others
Social interaction	<i>Rule compliancy</i>	When I take the RER/Suburban train, I appreciate it when other passengers avoid talking too loudly on the phone, playing their music loudly, etc.
	<i>Interaction needs</i>	I find it nice to be able to interact with other people on my RER/Suburban train journey
	<i>Intimacy needs</i>	I appreciate being able to be relatively isolated from other passengers when I take the RER/Suburban train
	<i>Relational safety</i>	I feel comfortable communicating with other passengers on the RER/Suburban train
Space, aesthetics and sensory ambiances	<i>Personal space</i>	I have enough space in the RER/Suburban train to feel comfortable during my journey
	<i>Outside environment aesthetics</i>	I sometimes find the view outside pleasant when I travel by RER/Suburban train
	<i>Vehicle interior aesthetics</i>	I like the interior of the RER/Suburban train carriage (colours, design, state of cleanliness, etc.) when I travel
	<i>sensory ambiances-smell</i>	I sometimes enjoy certain smells or perfumes during my RER/Suburban train journey
	<i>Sensory ambience-temperature</i>	I sometimes find the temperature in the RER/Suburban train pleasant
	<i>Sensory ambience-sound</i>	I enjoy the sound ambience inside the RER/Suburban train during my journey
	<i>Sensory ambience - kinesthesia</i>	I find the feeling of movement (fluidity, acceleration, vibrations, ...) pleasant when I am in the RER/Suburban train
	<i>security - aggression</i>	I am not afraid of being mugged when I travel by RER/Suburban train
Feelings of in/security	<i>Security - accident</i>	I am not afraid of having an accident when I travel by RER/Suburban train
Control of the trip	<i>Control of time</i>	With the RER/Suburban train, I feel in control of when I leave and how long my journey takes
	<i>Independence and freedom</i>	I feel free when I travel by RER/Suburban train
	<i>Ease of access</i>	I appreciate the easy access to the RER/Suburban train stations I use
Multiactivity and attention load	<i>Attention overload</i>	Sometimes I have to concentrate on finding my way around, not making mistakes or missing my destination when I travel by RER/Suburban train
	<i>Attention underload</i>	I find it nice not to have to concentrate on my journey when I travel by RER/Suburban train
	<i>Multiactivity</i>	I appreciate being able to watch a film, play, read, work, etc. during my RER/Suburban train journey
Information availability	<i>Information availability</i>	I appreciate having access to the information (itinerary, timetable, journey time, etc.) I need when I travel by RER/Suburban train
	<i>Information reliability</i>	I am sometimes satisfied with the reliability of the systems I use to get information about my RER/Suburban train (application, website, station display)
	<i>Information system usability</i>	I appreciate the simplicity and ease of use of the information systems on my RER/Suburban train (application, website, station displays)

(Private car, Bus, Transport-related walking, Tramway, Intercity & mainline Train). Indeed, only 32% to 42% of regular users of these modes estimates that it is an important source of their psychological Comfort. Conversely, between 68% and 58% evaluates this specific

comfort source as not very or not at all important. "Personal Norms" was also perceived as a not-important comfort source for 2 modes (Metro, Intercity & mainline Train). We also found lowest scores for "Interaction needs" for 2 modes (Metro, RER/Suburban train)

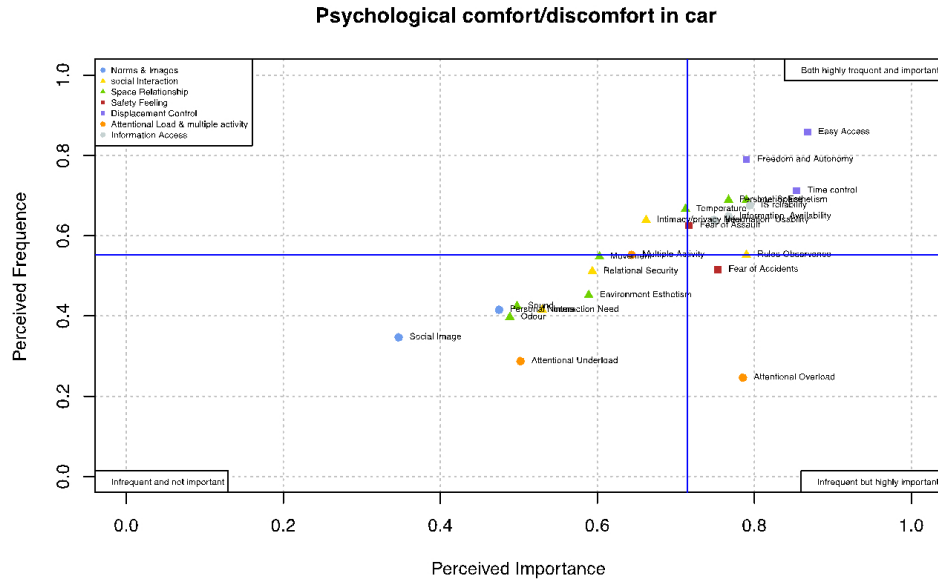


Figure 1: Importance and frequency of sources of psychological comfort and discomfort sources associated to private car

characterised by a high affluence, or even congestion, which could explain this result. The comfort source that scored the lowest in terms of importance for the Cycling Cycle and station-based bike sharing modes was “Multiple activity”, which is consistent with the driving activity and the attention it requires. On the other hand, “Easy Access” was assessed as the most important comfort source for 5/8 modes (Private car, Bus, RER/Suburban train, Intercity train and mainline train, Tramway). “Time Control” was associated to 2 distinct modes (Tramway, Bike and station-based bike sharing) as well as Assault safety (Metro, Transport-related walking). “Accident safety” was also considered as the most important comfort source associated to Transport-related walking. Finally, “Intimacy Need” was evaluated as the most important comfort source in the context of using Cycling Cycle and station-based bike sharing. To summarise, while most of investigated comfort sources are relevant across transport modes, “social images” and “personal norms” are judged as little importance and “Easy access”, “Time control” and “Assault safety” are amongst the most important. Interestingly, the perceived importance of sources is partially ranked differently depending on the mode, which can be interpreted as the fact that frequent users of the mode adapt their comfort expectations in relation to the mode constraints relatively to their own context. Moreover, the close median scores across the modes might suggest that commuters’ profile differ qualitatively rather than quantitatively in what they consider as important sources of comfort.

3.1.2 A contrasted experience of comfort source frequency between individual and shared modes of transport. The frequency of positive experience can be contrasted between modes with a median score greater or equal to .50 – and thus for which the experience leans toward psychological comfort – and those with a score lower than .50 (Table 4). This latter case means that more than half of the regular

users of the mode estimates that they experience rarely or never the targeted comfort source, i.e. this comfort source can be considered as largely absent. Private car, bike, and station-based bike sharing and transport-related walking are associated to a mostly frequent positive experience, whereas exposure to the comfort sources appears less frequent for Tramway, Bus, RER/Suburban train, Metro, Mainline Train/Intercity. This can be interpreted as opposing essentially individual-oriented modes against public transport modes that require to share space with others. These results also suggest that the dichotomy between individual vs collective-oriented transport encompass a set of varied comfort sources to be further scrutinised. We subsequently look at the major sources of comfort and how they are distributed across the modes. The sensory dimension of pleasant Odour is the less frequently experienced comfort source in five modes (TER/Intercity Train, Metro, RER Suburban train, Bus, Tramway). Attentional overload is the less frequent source of comfort associated with driving an private car, while Social Interaction is the less frequent comfort source related to transport-related walking. Finally, the lowest level of positive experience related to Information usability is associated to bike and station-based bike sharing. Conversely, Attentional overload is perceived as the most frequent sources of comfort experience for the 3 rail-guided modes (Metro, RER/Suburban train, Intercity train/main line). Easy Access is associated to 3 quite different modes: Private car, Bus and Tramway. While Easy access as a comfort source can be simply related to owning or being provided a private car, it is possible that the regular users of the bus and tramway refer to the combination of proximity of stations and regularity as their main and higher frequent source of comfort. Freedom and Autonomy are the highest source of comfort for 2 individual-oriented modes: transport-related walking and bike and station-based bike

Table 4: Importance and frequency of exposure to sources of comfort in eight most commonly used modes of transport

Modes	N	Source Importance			Median score	Frequency of exposure	
		Median score	Lowest score (concerned source item(s))	Maximum score (concerned source item(s))		Lowest score (concerned source item(s))	Maximum score (concerned source item(s))
Private car	219	0.72	0,35 (Social image)	0,87 (Easy Access)	0.55	0,25 (Attention Load)	0,86 (Easy Access)
RER/Suburban train	382	0.70	0,34 (Interaction need)	0,85 (Easy Access)	0.36	0,12 (Smell)	0,75 (Attention load)
Bike (personal or service)	31	0.68	0,39 (Multiple Activity)	0,84 (Privacy; Time control)	0,53	0,34 (Information Usability)	0,74 (Time control, Freedom & Autonomy)
Bus	161	0.68	0,37 (Social Image)	0,87 (Easy Access)	0.37	0,16 (Smell)	0,63 (Easy Access)
Metro	244	0.66	0,40 (Personal norms; Interaction need)	0,84 (Assault Safety)	0.33	0,11 (Smell)	0,67 (Attentional Load)
Intercity train and mainline train	19	0.66	0,32 (Perso.norms; Soc. Image)	0,84 (Easy Access)	0,32	0,00 (Smell)	0,79 (Attention underload)
Transport related walking > 10 minutes	141	0.65	0,42 (Social Image)	0,82 (Assault safety; Accident Safety)	0.50	0,25 (Social Interaction)	0,73 (Freedom & Autonomy)
Tramway	53	0,64	0,34 (Social Image)	0,80 (Time control; Easy Access)	0,43	0,19 (Smell)	0,62 (Easy Access)

sharing. Finally, Time control is also the highest positive source of comfort for bike and station-based bike sharing.

3.2 A focused analysis of the comfort/discomfort dimensions of the five most used modes

The following section is limited to the five modes with more than one hundred respondents in our sample (car, metro, bus, walk and RER/suburban train) in order to illustrate a more comprehensive approach to the proposed C/D dimensions (Table 3). Up to 24 C/D dimensions grouped into 7 more abstract categories can thus be compared (Table 5) and ordered to support further investigation about mode choice determinants and transport users experience, the development of solutions to reducing car use, and facilitating the shift towards more environment-friendly transport modes. From a descriptive viewpoint, most of the dimensions seem to be relevant the evaluation of sources of comfort/discomfort as only from 3 to 6 sources are considered as of little importance depending on the mode. As highlighted above, one source (Social Image) appears unimportant across the five modes. Interestingly, two sources (Interaction needs and Relational safety) are considered as unimportant for all but one mode: private car. Interaction needs is perceived as unfrequently fulfilled for this mode, as for the other modes. In

contrast, 16 C/D sources are consistently judged as important whatever the mode, although with variations in their perceived level of importance according to the mode.

The other sources are perceived as important or not depending on the modes. For example, Personal norms are perceived as important sources only for two modes (Transport-walking and Bus), whereas Smell and Attention underload are important sources for all modes but the private car. Sound ambiance is considered as important for users experience in three modes (Bus, Transport-walking, RER/Suburban train) while Kinaesthesia is considered as important for Car and Bus. The perceived frequency of exposure to sources of comfort also differs according to mode, as testified by median values (Table 5), especially within the sources perceived as important by their users. Considering sources perceived as important, two modes (Car and Transport-related walking) exhibit a majority of sources perceived as comfortable, i.e. as frequently experienced. Car generates infrequent exposure to only 3 comfort sources (Social interaction, Environment aesthetic, Attention overload) out of 16 sources of Comfort. Transport-related walking is characterised by 7 infrequent exposures to comfort sources (Smell, Sound, Safety from aggression, Safety from accident, Multiactivity, Information System reliability, Information Usability) out of 11 sources associated to comfort.

The three other modes exhibit from 12 to 18 infrequent comfort sources. Two important sources are systematically perceived as frequently experienced whatever the modes: Easy access and Rule observance. The former can be interpreted straightforward as reflecting the fact that users were questioned on modes they heavily use, and thus for which accessibility is a prerequisite for being used. Rule observance, beyond such a converging result, relates to classes of behaviour specifically adapted to each mode context: the rules are about phoning and listening to music without caring about other users for the train and metro, whereas they are about sharing the on-the-road environment for the car and transport-related walking. This result suggests that users perceive that social rules related to mode-specific behaviour are respected most of the time, and that appears to be true across the five modes.

Several differences could be related to intrinsic characteristics of the modes. For example, Intimacy is perceived as a frequently encountered source of comfort in the case of private cars and transport-related walking, in contrast to the low frequencies reported by users of collective public transports (Bus; Metro, RER/suburban train). Conversely, Interaction Needs is considered as an important comfort source but is reported as too scarcely experienced in the sole case of private car users. A similar pattern is observed relatively to Personal space. Another clear dichotomy between modes is highlighted at the level of Time control and Freedom and autonomy: both sources appear as important dimensions of psychological comfort in the case of Car and Transport-related walking, and oppositely uncommon in the case of Bus, Metro and RER. The car driving, metro and RER environment aesthetic are all associated to infrequent experiences, while they are commonly associated to a source of comfort in the case of Bus and transport-related walking. The opposite pattern is found for Interior aesthetic/appearance and Temperature, which are dimensions of the surrounding environment and that are not actually under the control of the users except when they use their car. Interestingly, two sources related to space (Smell, Sound) are mostly associated to discomfort in all the modes, but not deemed as important when considering their car. The same is the case for sensory dimensions related to the Kinesthetic ambience, although this source was mostly considered as not important, except for the Bus and the car. The two dimensions of feelings of safety (Aggression and Accident), are considered as a source of comfort when using a car, whereas the other four modes are given rise to little or even no comfort experience. An exception stems from the RER for which Accident safety is also perceived as a source of comfort.

Attention overload is the only source that contrasts the private car with the four other modes (where it is associated to a frequent comfort source). Attention underload is infrequent in the case of car, bus and metro, but associated to comfort in both transport-related walking (e.g. no need for attention when I know the trip) and RER (as if more latitude to perform other activities in parallel to the trip was perceived, minimising the potential of being forced to be inactive and exposed to a situation of attentional underloading). The latter interpretation is supported by the perception of Multiple activity as a source of comfort by the RER / Suburban train but not by Bus and metro users, as well as by pedestrians. This dimension is interestingly perceived as a source of comfort by car users, although the reasons are less straightforward to analyse. A possible

explanation could lie in that parallel activities are made possible through the use of services related to digital equipment in the car (e.g. listening to the radio, personal music or making a call).

Finally, the three dimensions related to Traveller Information Systems (IS) and services also provide interesting elements. Information availability is scarcely associated to experience of comfort only by Bus users, suggesting a deficit specific to the bus network in Paris and its suburbs. Conversely, this comfort source appears to be a frequent experience for four other modes, although probably for different reasons depending on the nature of information (road congestion, rail incident, etc.) and supports (screens, personal smartphones, etc.). IS reliability and usability show a common pattern distinguishing between car and metro, where they are perceived as a source of comfort, and conversely Bus, RER and walking where they are not. These results could indicate differences in the nature of expected information and the type and the quality of human-system interaction.

4 DISCUSSION AND PERSPECTIVES

This study describes an approach of the user experience of transport modes through the multiple dimensions of psychological comfort using a questionnaire based on previously identified situations (Allinc & al. 2015; Allinc 2018). The results provide insights for improving the comfort of different modes of transport by identifying some key dimensions to work on for a better user experience during transport situations. Dimensions such as social norms and social representations associated with the most commonly used modes of transport appear overwhelmingly considered to be of little importance, while expectations regarding an instrumental dimension such as Time control, Accessibility and Safety remain high overall, alongside other dimensions specific to the various modes. Indeed, a common set of 16 comfort sources from broad categories like Social Interaction, Space, Aesthetics and Sensory Ambiances, feeling of Safety, Control, Multiple activity and Attention load, can be used to characterise and evaluate the dimensions of commuters' experience in relation to the transport modes they use. Furthermore, some dimensions appear to be more specific to some modes.

Beyond a certain level of perceived comfort, a hierarchy of psychological comfort dimensions emerges that differs according to the mode of transport, suggesting an adjustment of expectations on the part of frequent users. This confirms the importance of integrating and studying the psychological dimensions of comfort in more detail, over and above the historical aspects of physical ergonomics, and of developing tools to measure them. These dimensions could offer pathways into how to improve public transport systems and infrastructure for soft modes, by indicating the sources of discomfort and comfort, and how to encourage modal shift from private car to shared or soft modes. Identifying the obstacles and possible psychological levers associated with the experience of public transport users is an important issue in guiding the design of future modes and vehicles towards low-carbon mobility. While most of previous research was generally focused on one type of mode assessing very few dimensions (such as cost and time), attitudes or the comparison of scenario of transport modes through stated preference experiments to identify intentions of use, our approach enables to present a more extended view of comfort and discomfort situations and

Table 5: Importance and Frequency of comfort /discomfort sources scores for the five most used transport modes in our sample. Importance scores above .50 correspond to items rated as “somewhat important” or “very important” by more than half of the participants (black)s, while lower scores indicate the opposite (light grey). Frequency scores above .50 indicate psychological comfort as more than half of the participants rated the positive situation depicted in the item as occurring “frequently” or “very frequently”. Regarding the Frequency, the higher the score, the higher the psychological comfort as the share of participants evaluating the item positively (in bold green). In contrast, scores below .50 correspond to discomfort (in italics red if the dimension was rated as important, otherwise in orange).

Sources of comfort	Sub-dimensions	Car (N=219)		Bus (N=190)		Metro (N=210)		Transport-Walking (N=141)		RER/suburban train (N=193)	
		Imp./Freq.		Imp./fréq.		Imp./ Freq.		Imp. / Freq.		Imp. / Freq.	
Personal values and social image adequacy	Personal Norms	0,47	0,42	0,52	0,32	0,40	0,28	0,65	0,52	0,38	0,33
	Social Image	0,35	0,35	0,37	0,25	0,42	0,25	0,42	0,32	0,36	0,23
Social interaction	Rules Observance	0,79	0,55	0,78	0,54	0,80	0,52	0,81	0,50	0,83	0,66
	Interaction needs	0,53	0,42	0,42	0,25	0,40	0,20	0,43	0,25	0,34	0,20
	Intimacy/privacy Need	0,66	0,64	0,66	0,42	0,71	0,33	0,76	0,60	0,72	0,43
	Relational Security	0,59	0,51	0,43	0,24	0,44	0,18	0,49	0,35	0,40	0,22
Space, aesthetics and sensory ambiances	Personal Space	0,77	0,69	0,76	0,29	0,75	0,19	0,79	0,61	0,80	0,32
	External Environment aesthetics	0,59	0,45	0,63	0,51	0,52	0,27	0,80	0,52	0,54	0,32
	Interior env. aesthetics	0,79	0,69	0,65	0,28	0,67	0,20	NA	NA	0,67	0,25
	Sensory ambience - Smell	0,49	0,40	0,53	0,16	0,55	0,11	0,62	0,35	0,56	0,12
	Sensory ambience -Temperature	0,71	0,67	0,74	0,29	0,69	0,22	NA	NA	0,75	0,23
	Sensory ambience - Sound	0,50	0,42	0,53	0,27	0,50	0,17	0,60	0,32	0,56	0,20
	Sensory ambience - Kinesthetic	0,60	0,55	0,61	0,29	0,50	0,25	NA	NA	0,49	0,27
Feeling of safety/insecurity	Safety from aggression	0,72	0,63	0,83	0,45	0,84	0,34	0,82	0,49	0,85	0,38
	Safety from accident	0,75	0,52	0,81	0,42	0,78	0,40	0,82	0,45	0,80	0,55
Control of the trip	Time control	0,85	0,71	0,78	0,36	0,79	0,46	0,81	0,67	0,78	0,34
	Freedom and Autonomy	0,79	0,79	0,62	0,35	0,61	0,38	0,79	0,73	0,68	0,38
	Easy Access	0,87	0,86	0,87	0,63	0,82	0,65	0,79	0,62	0,85	0,66
Multiactivity and attention load	Attention Overload	0,79	0,25	0,71	0,56	0,55	0,67	0,58	0,62	0,67	0,75
	Attentional Underload	0,50	0,29	0,72	0,47	0,65	0,45	0,73	0,51	0,73	0,58
	Multiple Activities	0,64	0,55	0,58	0,37	0,58	0,35	0,59	0,43	0,67	0,51
Information availability	Information Availability	0,77	0,65	0,77	0,45	0,73	0,52	0,65	0,50	0,80	0,55
	Information system reliability	0,79	0,68	0,77	0,46	0,77	0,50	0,65	0,42	0,81	0,42
	Information system Usability	0,75	0,64	0,77	0,46	0,84	0,50	0,65	0,45	0,80	0,46
Median		0,71	0,55	0,68	0,37	0,66	0,33	0,65	0,50	0,70	0,36
Interquartile range		0,23	0,16	0,21	0,17	0,25	0,24	0,20	0,20	0,25	0,28
Min		0,35	0,25	0,37	0,16	0,40	0,11	0,42	0,25	0,34	0,12
Max		0,87	0,86	0,87	0,63	0,84	0,67	0,82	0,73	0,85	0,75

to compare between them for different modes. Indeed, we believe that the proposed dimensions and subdimensions of psychological comfort shed more light on the variety of dimensions of users experience in transport modes and their perceived importance. This proposed structure of multiple sources of comfort/discomfort appears to be general and robust enough to cover a wide variety of transport modes as a design support, allowing the identification of expected design goals and criteria for each dimension. In this sense, it can be used to support requirements engineering as well as fine-grained evaluation and comparison between different variants and mobility solutions in transport projects.

A point not currently analysed is the inter-individual variability of perception of the multiple dimensions of psychological comfort and the involved factors, both individual (e.g. age), spatial (e.g. transport access, place characteristics) and other socio-demographics factors. In addition, it would be interesting to analyse the dynamics and interactions of the comfort and discomfort dimensions over time and how they relate to each other. A broader collection of situations related to the different dimensions is also a perspective, as it would provide alternative items and content to address the evaluation of user experience in transport modes along their evolution.

Our study has several limitations. Due to the exploratory nature of this study, the questionnaire was first tested for its internal consistency, but should be further studied in terms of its structure and assessed in terms of convergent validity. The latter will require the use of a pre-existing questionnaire targeting similar dimensions, at least at the conceptual level, which has not yet been identified at this stage. In addition, our sample is somewhat specific in that all participants use cars, and the Paris suburbs are well equipped in terms of transport services and infrastructure. This leaves open the question of the extent to which our results can be applied to an area that is drastically different in terms of transport equipment. The experience and psychological comfort of users probably depends at least partially on what modes of transport they can access to, which is likely to influence users' expectations and prioritization of comfort dimensions. Moreover, this empirical picture is situated

at a specific moment in time. Therefore, the evolution of modes in the future will probably transform the comfort/discomfort felt with these modes.

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