SLIDE 1: INTRO

SLIDE 2: The background of this study stems from two main points. From one side there are sounds from neighbours which unfortunately are a very common issue and cause a lot of complaints and annoyance, and from the other side there is the trend towards sustainability, which is promoting the use of lightweight constructions, that indeed results to be more sustainable under an environmental point of view, however, are at risk of being not so much acoustically sustainable for residents. In fact, acoustic comfort in lightweight buildings is still an open matter, and sound insulation is hard to achieve if compared to traditional concrete or masonry construction types.

SLIDE 3: Accordingly, we carried out a series of laboratory-based experiments for understanding the response to neighbours sounds in lightweight timber buildings. the first experiment regarded the emotions and physiological responses elicited when people are hearing footsteps from upstairs, and speech and music from siding units. In the second experiment, we collected the EEG Alpha waves in response to the same sound stimuli, and in the third experiment we focussed on the annoyance caused by upstairs footstep sounds.

SLIDE 4: As you can, see aural diversity was not intended as having a main role in the project, however it turned out to be inherently part of it, as in all these experiments we kept in consideration non-acoustical factors, which draw attention on some of the many personal characteristics affecting the different response to sound of different residents. For instance, noise sensitivity was introduced in all the three cases. In the second and third experiment, attitude towards neighbours was also investigated, and in the third study we introduced the effect of circadian rhythm type. As you can see, with the progression of the experiments more and more non-acoustical factors were introduced, as we realized, not only about their importance in mediating the responses, but also about the lack of investigation on the matter. To assess them, we used the questionnaires I reported here: for the noise sensitivity we used NoiSeQ questionnaire, developed by Shutte at al. back in 2007, for the attitude towards neighbours we adapted a five-item questionnaire which were extracted from a study of Park et al. in 2019, when she carried out a series of in-depth interviews with people living in multi storey buildings, in which she inquired about their attitude towards neighbours. From their answers these five items were extracted. As much as it regards the circadian rhythm type this relied on the morningness eveningness questionnaire developed back in 1972 by Horne at al.

SLIDE 5: lets now move on to experiment number one. In this experiment we investigated the emotions and physiological responses elicited by neighbours sounds, and how these were affected by noise sensitivity. The experiment was made up of a sequence of sessions, in which sounds from neighbours were presented singularly or in combination. Each session was composed of a sequence in which we presented a baseline, the stimulus, and a questionnaire about arousal and valence, which were rated using the self-assessment manikin that you can see here reported. Before the experiment, noise sensitivity was assessed, and participants were then divided into a low and high noise-sensitivity groups based on the median of their overall score. Throughout the experiment we monitored four physiological responses, which were the facial Electro myography on two muscle groups of the face, the heart rate and electrodermal activity, and the respiration rate. In the last picture you can see the setup of the experiment, which was carried out in a listening booth with a low background noise level, and participants were hearing to sound through headphones and subwoofer.

SLIDE 6: the results of the experiment in terms of emotions are resumed in this slide. In the first graph the emotions rating in response to neighbours sounds are compared to previous investigations which included emotional rating of everyday sounds. The interesting thing here is to notice that previous study categorized footsteps sounds as having a neutral emotional content, but in our cases, because the footstep sounds were heard through different partitions, they elicited a very different emotional response. Also, the effect of different floors can be clearly seen, as the emotional content of the very same sounds changed greatly based on its SPL. Similarly with speech sounds, so we could see that if we hear the neighbours talking clearly or if we barely hear the conversation, it makes a huge difference under an emotional point of view. In the second graph we can see how all the sounds heard in combination tend to align along the defensive motivation circuit. The appetitive and defensive circuits are based on a theory which suggest that stimuli can be broadly divided in stimuli promoting survival, to which we tend to be attracted to (that elicit the appetitive motivation circuit) and stimuli which are threatening us and stimulate us to escape from them (so elicitors of the defensive motivation circuit). From our investigation, the sounds from neighbours are aligning along this defensive motivation circuit, and this suggest, they generate a sense of threat.

SLIDE 7: The second interesting thing, is that the emotion ratings from each participant scatter significantly as we can see in this slide, especially for the single sound sources, for which the trend is not so clear. This was just to give an impression and question on the use of ‘average’ data, especially in the assessment of emotion ratings.

SLIDE 8: In terms of physiological responses, hearing neighbours sounds caused significant change from baseline in our physiology. The electro myography showed activation in the Corrugator Supercilii muscle, which is generally activated in response to unpleasant stimuli, and deactivation in the Zygomaticus muscle group which is generally activated in response to pleasant stimuli. Additionally, we found that the heart rate decelerates, the electrodermal activity decrease, and the respiration rate decelerated when listening footsteps and speech and accelerated when listening to music. Some of the differences were statistically significant among sound sources, however I'm not going into this in detail, it was just to give you an impression of the significant physiological changes detected after exposure to sounds, which many residents are commonly hearing every day.

SLIDE 9: lets now move on to the effect of noise sensitivity on emotions ratings. Overall, when considering all the sound sources presented, the difference between the two noise sensitive groups was significant for arousal ratings, and not significant for valence ones. The difference in the emotional response between the low and high noise sensitive participants for the footstep sounds, was significant across sound pressure levels in arousal (as you can see in the first graph), while the valence dimensions started to show significant differences above a certain SPL, as reported in the second graph. This different influence of noise sensitivity, between arousal and valence, may be since the use of the valence scale was reduced to its unpleasant half part, as participants were almost never happy when hearing any of the neighbours sound presented, so the variation in valence was shorter if compared to arousal.

SLIDE 10: the effect of noise sensitivity on physiological responses was never significant in this experiment. However, I reported here few graphs to show that there was a detectable difference in some cases. For instance, in the activation of the Corrugator (in the first graph) we can see that the people with the high noise sensitivity showed increased activity if compared to people with low noise sensitivity, and similarly also with the respiration rate (in the last graph), when hearing footsteps combined with speech and music, participants with high noise sensitivity showed acceleration in respiration rate, while the participants with the lower sensitivity, didn't show that, so I think is because we use very many stimuli with very similar emotional content and we couldn't expect a much stronger difference between the two noise sensitive groups, but a difference is there so it is likely that in real-life scenario this effect is more marked.

SLIDE 11: Lets now move on to the experiment number two. in this study we looked at the EEG Alpha waves response to neighbour sounds, and the effect of both noise sensitivity, and attitude towards neighbours on the response. I reported here the outline of the experiment, which was a sequence of stimuli, in this case we simply assessed what was happening in the EEG response while participants were listening to each sound for 20 seconds. The sounds were the same as used in the previous experiment, here you can see some picture from the test, which was conducted in collaboration with the Fire Insurers Laboratories of Korea that helped us through this period of suspension of face-to-face experiments in the

UK. Participants were divided in two noise sensitivity groups based on the median rating of the overall NoiSeQ-R score and grouped into having a more or less positive attitude toward neighbours based on their overall attitude questionnaire score. From the EEG response we extracted Alpha waves, which are also referred to as 'restoration rhythm', as they are associated with relaxation and with subjective preference. In this study, we wanted to see if neighbour sounds and non-acoustical factors influenced Alpha waves, and if this could inform on which residential acoustic scenario would be the preferred by potential residents with different characteristics.

SLIDE 12: after extracting, for each sound source, the Alpha waves response, this is what we found. In the first row we can see the running EEG along the 20 seconds of stimuli presentation. From the running EEG we extracted the average value which are the one used to conduct statistical analysis and you can see on the bottom row. We found that when comparing different partitions through which footsteps were heard (for instance footsteps at 30 or 55 dB) the difference in Alpha activity elicited, was statistically significant, this difference was not significant for speech, but it was for music, and having the opposite trend. This was quite expected because the music clip we used was a quiet piece of classical music played on the piano, so at the higher sound pressure level was overall preferred if compared to the barely audible music clip.

SLIDE 13: more of interest about the different way in which everyone hears, we can see that the effect of noise sensitivity on the Alpha waves response was significant for footsteps and speech at both sound pressure levels, and for music at the highest sound pressure level. This means that individuals with low noise sensitivity showed larger Alpha waves activation if compared to individuals with high noise sensitivity. This was quite striking because it clearly shows how individuals with different sensitivity to noise respond instantly and 'objectively' in a different way when exposed to everyday sounds. Particularly, significantly higher Alpha activity, is elicited in individuals with low noise sensitivity, as indication that their relaxation is less likely to be affected by the presence of sounds from neighbours.

SLIDE 14: we also found that the Alpha activity was significantly different among subjects with a more or less positive attitude towards neighbours. According to our findings, people having a good attitude towards neighbours tend to have a higher Alpha activity when exposed to sounds, so, again, their relaxation is less likely to be affected by the presence of neighbours sounds, if compared to people who have a poor attitude towards neighbours. And this was despite the sound insulation performance of floor and wall being good or poor.

SLIDE 15: Finally, the experiment 3 investigated the annoyance response to footstep sounds from upstairs, and the effect of noise sensitivity, attitude towards neighbours, and circadian rhythm type. This experiment was conducted in collaboration with the Institute of Advanced Science and Technology in Osaka, Japan. The experiment was made up of three sessions in which we presented footstep sounds variating in spatial impression and sound pressure levels. In this case, we presented sound spatially using an array of loudspeakers and, we relied on the use of a Head-Mounted Display to show participants an immersive picture of a living room during day and night-time. Participants were divided in two noise sensitivity groups based on the median rating of the overall NoiSeQ-R score, grouped into having a more or less positive attitude toward their neighbours based on their overall Attitude questionnaire score, and divided between M and E type based on the MEQ score.

SLIDE 16: The outcome in terms of annoyance was that the footstep sounds provoked different annoyance based on both spatial features and sound pressure levels. In this case we used the inter-aural cross correlation to identify the spatiality of sounds. According to this parameter, when it is closer to one it is easier for people to localize the sound, when the IACC is closer to 0 instead, it is harder to localize the sound source. It was interesting to find out that both, the spatiality, and the sound pressure level made for appropriate characteristics to look for, when subjectively investigating footsteps sounds. You can see here that annoyance ratings increased with the IACC in the first graph and, also with the sound pressure level, in the second graph. Just to underline how spatial characteristics of sound exposure could get more attention as having a significant influence on the way sounds are perceived, not to mention the fact that every person may perceive differently sound spatial cues.

SLIDE 17: Let's look at the effect of noise sensitivity. We can see that the annoyance ratings are significantly different between participants with low or high noise-sensitivity, so if we ordered the footsteps sound stimuli based on their IACC value, or based on their sound pressure level, however the people with high noise sensitivity rated significantly higher annoyance if compared to people with low noise sensitivity.

SLIDE 18: Similarly, the attitude towards neighbours showed to have significant effect on the annoyance, and participants with a poor attitude towards neighbours showed significantly greater annoyance. Also, in this study, we found a correlation between the score of the noise sensitivity questionnaire, and the attitude towards neighbours questionnaire, which was intriguing because we don't know yet if it is the poor attitude toward neighbours which prompt higher noise sensitivity, or if it's the opposite. However, it was a negative significant correlation, meaning that, in this investigation, higher noise sensitivity was correlated with a poorer attitude towards neighbours.

SLIDE 19: And finally, in this study we also wanted to check if the circadian rhythm type of participants influenced perceived annoyance. It was recently suggested that auditory functions are under circadian regulation. For example, it was found that noise trauma during nights had severer consequences if compared to noise trauma heard during the daytime. According to our findings, participants with a definite Evening type rated annoyance significantly differently from participants with a definite Morning type. Particularly, Evening type participants were more annoyed by footsteps sounds despite sounds being presented in daytime or night-time conditions.

SLIDE 20: to sum up, non-acoustical factors affect the response to neighbour sounds, suggesting that every resident is affected differently by acoustics events. Particularly noise sensitivity was found to significantly affect arousal, Alpha waves and annoyance elicited by neighbour sounds. Attitude towards neighbours was found to significantly affect both Alpha waves, and annoyance ratings provoked by footsteps sounds. The circadian rhythm type was also found to significantly affect the annoyance elicited by neighbours footsteps. To conclude, the presentation highlighted how personal characteristics should be given more attention in the context of building acoustics, as we do not all hear sounds in the same way, and just as acoustical factors, these personal variables may inform on how residents could or could not be affected by certain indoor soundscapes.

SLIDE 21: OUTRO