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Understanding the Mechanisms behind Changing People's Recycling Behavior at Work by Applying a Comprehensive Action Determination Model

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Abstract: This study moves toward a better understanding of the mechanisms behind changing people's recycling behavior at work by mapping out which pathways and variables change in recycling behavior as triggered by interventions. A questionnaire was designed based on the theory of planned behaviour, the norm-activation model, habits, and a comprehensive action determination model (CADM). The data was collected in two rounds: before the intervention and after a three-month pilot period with implemented interventions using a sample of n=1269 students and employees. The CADM model appears to be a good fit with the data. The results from the structural equation modelling indicate the pathways to influencing behavioural change. The most important psychological variables accounting for waste separation behaviour are intentions, perceived behavioural control, personal norms, social norms and habits. No difference in waste separation behaviour was observed in the control building. Interventions targeting the increase in waste separation raised participants' intentions to engage in such behaviour. Results indicate that waste separation at work must go beyond technical aspects to include various key elements of sustainability to ensure success. Furthermore, understanding human behavior is key in determining the performance and success of an integrated and effective recycling intervention strategy.

Keywords: waste separation; recycling behaviour at work; interventions; comprehensive action determination modelling

1. Introduction

For many years now, waste recycling has attracted considerable attention from policy makers and other environmental stakeholders in an attempt to address the issues of waste reduction [1]. The increasing awareness of waste and concern about its effects has led to a wide range of studies aimed at understanding factors that may enhance waste recycling behavior, which for individual consumers or workers translates to waste separation. Workplace waste is now attracting more attention than other waste-generation contexts, such as households [2]. While different factors influencing household waste recycling behaviour have been identified and documented [3], workplaces have been relatively overlooked [4].

Past literature reflects little understanding of the impact of psychological factors with regard to waste separation behavior at the workplace and how interventions affect behavior and its psychological antecedents. This study attempts to close this gap by investigating how a pre-designed intervention affects psychological variables that are known to be predictors of recycling. By applying a comprehensive and rigorous psychological model, this research also results in insights into the determinants of waste separation behaviour.

Previous studies address the problem of waste in the context of the workplace and relate it to recycling at home, which is much more often studied [5–7]. The general consensus of past literature is that separating recyclable fractions like paper, glass, metal or plastic from household waste is considered a significant contribution to environmental protection as it saves natural resources while reducing the amount of household waste that has to otherwise be treated (e.g., [8,9]). Pro-environmental intentions at home may differ from intentions at the workplace, as households are usually liable for costs of waste disposal while such costs might not be apparent to people at work [6]. The unclear understanding of the specific nature of employees' involvement in pro-environmental behaviour highlights the need for further investigation of such behaviours. Therefore, this study addresses the effect of interventions on psychological determinants of waste separation behaviour at the workplace, in this case a university setting. This study is developed within a Norwegian context. Given that the university chosen is located in Norway, it is acknowledged that the results of the study could vary according to these characteristics.

Unlike other environmental problems, such as global warming or deforestation, the problem of waste is categorized as a problem with clearly identified solutions since much of the waste thrown away can be recycled [10]. "Recycling is defined as the separation of materially salvageable items from composite trash" ([11], p. 4) Recycling is one of the major practices that reduce the amount of waste while at the same time contributing to production of new goods. It reduces the amount of waste that ends up in landfill sites, and it cuts down on the amount of material needed from the natural environment. As secondary material production pollutes less than extraction and processing of new materials, recycling is a form of environmental conservation [12].

Universities are a relevant context for studying as universities have a large number of students and staff, a broad scale of complex activities, and many operational processes. Furthermore, they produce high volumes of waste that have an impact on the environment [13]. Researchers have noted that universities and colleges have a moral and ethical obligation to act responsibly toward the environment and are expected to be the leaders for environmental protection [14]. Moreover, good waste management programs would set a good example for students and communities. Because universities play a key role in practices of sustainability, a closer look at their waste separation systems is important. These systems can be easily adopted by students, who will shape society in the future, and also by the society as a whole.

NTNU is one of the universities with the goal of becoming a green university. As part of its action plan, NTNU has created a project for the environmentally friendly handling of waste, with the aim of becoming a unique and outstanding institution [15].

As waste handling is a behavior deeply implemented in daily routines, habits as a psychological representation of the degree of automaticity in this domain have received considerable research attention. Habits are assumed to be predictors of repeated environmentally relevant behaviour [16–19]. In the context of environmental issues, habits are usually conceived as barriers against pro-environmental behavior since they lock people into non-environmental routines. Various studies have shown the strong impact of habits on recycling [20–23]. However, habitual behaviours related to the environment can be changed [24]. If interventions properly target the situational context, it might be possible to remove barriers in order to act toward a better environment [17]. For designing such structural interventions, a comprehensive model is suggested to integrate previous frameworks in order to better understand waste separation behaviour at work in a context that is highly characterized by existing and potentially interfering routines. The need to integrate psychological and objective situational variables to fully understand recycling behaviour has been repeatedly stated [16,24,25]. The *Theory of Planned Behaviour* (TPB) [26], the *Norm-Activation-Theory* (NAT) [27], and the *Value-Belief-Norm-Theory* (VBN) [28] to name a few have previously been applied to the area of recycling. Utilizing TPB, Cheung, Chan, and Wong [29] successfully applied TPB to explain students' participation in wastepaper recycling in Hong Kong while Ref. [30] used TPB to help investigate people's participation in the recycling program of the

British city Brixworth. The basic assumption of the theory is that people recycle if they form an *intention* to do so, which, in turn, is predicted by positive *attitudes* towards recycling, *subjective norms,* which are a representation of expectations of relevant other people (one may call it "social pressure"), and *perceived behavioural control*, which is a feeling of being able to perform the intended behaviour. The *Norm-Activation-Theory* (NAT) [27] assumes that in behavioural domains that carry a reference to morality—such as altruistic behaviour or pro-environmental behaviour (such as recycling)—*personal norms*, which are feelings of moral obligation to act, are a potent motivator of behaviour [31] applied NAT [27] to participate in a kerbside recycling program in a US neighbourhood. Thøgersen [32] also demonstrated that personal norms are a strong predictor of environmentally relevant behaviours. These personal norms, however, have to be activated when encountering a situation to become relevant. Three direct predictors of personal norms are awareness of needs (AN), *awareness of consequences* (AC) and *ascription of responsibility* (AR) [33]. AN is a person's awareness of the need for help, while AC is knowledge about the consequences of certain kinds of behaviour that might occur after a person performs the behaviour, and AR is the acceptance of responsibility for the behaviour [33]. Thus, a person needs to be aware of the unfavourable consequences of an action and believe that they pose a threat to others; moreover, he or she needs to acknowledge that his or her actions might avert the situation in order to engage in pro-social behaviour. Furthermore, a person has to be convinced that he or she is able to perform the behaviour in question (*perceived behavioural control*, PBC). Applied to recycling at work, this means that people might develop a feeling of moral responsibility to recycle, if they are aware of the negative consequences of not recycling, if they are aware that their behaviour has a significant impact on the waste problem at work, if they feel capable of recycling, and finally, if they experience the expectation of other people they value to participate in the recycling program. As recycling is a highly repetitive behaviour that is performed both often and under the same situational circumstances, it should be one of the behaviours with a high potential of becoming habitual [34]. If behaviour becomes habitual, the influence of deliberate processes such as intentions or personal norms diminishes and behavioural patterns become automatically activated as soon as a situational setting previously associated with the behaviour is encountered [35]. Cheung et al. [29] presented that past behaviour impacts recycling behaviour over and above the impact of the theory of planned behaviour context and Holland, Aarts and Langendam [36] further demonstrated the role of habits in recycling.

A key implication of past studies applying these theories is that they focus on one aspect, and underestimate the other aspects, and, thus, consequently, one model that fits to one specific domain might not be applicable to another domain. For instance, TPB focuses on intention and disregards personal norms, and NAT focuses on personal norms but underestimates the role of situational constraint. The habit concept addresses both intention and habit; however, it overlooks the impact of situational constraints and normative process. In an attempt to integrate the aforementioned models and individual habit strength and to avoid the weaknesses of the single models while providing a general model framework that would apply in a larger variety of situations, Klöckner and Blöbaum [37] proposed a model that they referred to as the "comprehensive action determination model" (CADM). CADM incorporates intentional, normative, situational, and habitual influences in explaining pro-environmental behavior, and has been successfully applied, with good empirical support, to a series of studies in different behavioural domains such as recycling, travel mode choice and energy-efficient investment behavior [37–40].

Unlike traditional psychology models of behaviour, the CADM model [37] postulates that individual environmentally relevant behaviour is determined directly by intentions (INT) and perceived behavioural control (PBC). In addition, it integrates habit strength as a third direct predictor of behavior (HAB). In addition, normative processes (i.e., social norms (SN), personal norms (PN)) do not influence behavior directly, but are mediated by intentional and habitual processes. Despite personal norms being considered stable, PBC could impact PN in the long run. In other words, situational influences deactivate personal norms if behavior, which is in line with norms, is not easy to perform [37].

Transferred to participating in a waste separation scheme at the workplace, this means that people separate their waste, if they have strong intentions to do so, feel capable of implementing their intentions and at least do not possess counter-intentional habits that could cause interference (for example, automatically throwing all waste into the same bin placed in the office). As a best-case scenario, they have formed a waste separation habit, which makes them automatically separate their waste at work. The intentions to separate are predicted by attitudes, perceived behavioural control, personal and social norms. By successfully performing a stable behavioural pattern in a stable situation, an individual generates (new) habits.

Tests of the CADM model in a meta-analysis across a large variety of environmentally relevant behaviours indicate that this model is applicable to a wider range of situations and behaviours while being more general than the individual models feeding into it [41]. We chose the presented comprehensive model as a theoretical framework to analyse the implementation of a waste separation regime because it helps with understanding why some strategies alone will most likely fail and how they need to be combined to design a practical intervention strategy.

In the present study, we thus employ the presented comprehensive psychological framework to study the behavioral and psychological effects of introducing a waste separation scheme in a university context. Since the waste separation system was introduced in a pilot building of the university first, it allows us to study the effects in comparison to the control condition in a second building in a pre-post intervention design. The research questions to be addressed are:

(1) Does the comprehensive modelling framework provide a good description of the factors impacting recycling at the workplace?
(2) Does the intervention package introduced in the pilot building change the level of central variables in the model, and, if so, which variables are these?
(3) Does the intervention package change the strength of the relations between the model variables or the model structure?

Ultimately, the question studied is if the model can explain through which pathways and variables the changes in recycling behavior are triggered by the interventions, thereby providing a better understanding of the mechanisms behind changing people's recycling behavior.

2. Materials and Methods

The following sections first describe the intervention package implemented by the university in one of its buildings. Then, the research design for this study will be presented. Finally, the measurement instruments and the sample will be described.

2.1. The Universities Waste Separation Campaign

The Norwegian University of Science and Technology (NTNU) is one of the largest institutions in Norway [42]. In 2013, NTNU decided to introduce a waste separation system to increase the recyclability of the waste produced at NTNU [15]. The project focuses on implementing various disposal bins for different kinds of waste, reducing the waste of furniture, finding solutions for disposal of dangerous waste such as batteries or electronic devices, finding alternative solutions for disposing of food waste, and reducing the use of paper by using online alternatives. Before rolling out the new strategy to the whole university campus, a pilot study started in April 2014 and lasted for three months in one building. One measure was to give students and employees options for separating plastic, glass and metal, batteries and electronic devices, bottles and cans that are returnable. The project group chose a building for the pilot study that represented most of the typical university aspects. It had lecture rooms, study rooms, laboratories, a cantina, various departments and teachers' offices, and also a private company housed in the same building. Strategic high-traffic points, where people most frequently passed by, were chosen for the new waste stations so that students, employees, and guests would have easy access to these stations. The pilot study also tested the removal of all individual garbage bins inside the private and common offices, so that the office occupants have to come to the waste stations to get rid of their garbage in the common waste stations by separating it there. Besides these structural changes in the waste collection infrastructure, the project group used various kinds of communication channels to inform and instruct users of the building about the use of the new waste stations. TV screens in the main corridors displayed information, flyers were placed in the cantina area, and information cards were distributed by the maintenance crew. The internal website of the university included information about the project and informed users about what types of waste could be separated into different waste stations and what types could be disposed of in another place. This website also provided updated information on which building achieved the goals of the project and showed actual results. The project group conducted meetings with employees of NTNU and private companies sitting in the building.

2.2. Design of the Study

For this study, the research team collected data both within the intervention building and a comparable control building without a change in the recycling system. Data were collected by paper-and-pencil questionnaires and most of the participants were approached in person asking for their participation. Students were approached in the cantina area, in the study rooms, in the PC labs, and during the lecture breaks. To motivate their participation, students were informed that they would receive small chocolates after participation. Most employees were informed about the study via emails from the department secretary and received the questionnaire in their university internal mail boxes. They were asked to return the completed questionnaires to the folder located in the secretary's office. Employees were not offered any treats. This may have caused them some inconvenience, as the number of participants from the employees' group was lower than expected: of the employees that have an office in the experimental building, 33 answered the questionnaire (about 40%).

The questionnaire was created in two versions, as there were two groups, experimental and control, and because the survey was administered twice, before and after the intervention. One version of the questionnaire was used in the first round for both the experimental and control group. The second round of the study was conducted four months later, when the pilot study was finished and users of the experimental building had become familiar with the new waste separation system. In the second round, the same questionnaire was used in the control group, as there was no difference in waste separation conditions in these buildings. The experimental group received the second version of the questionnaire, where items about intervention were included in addition to the items included in the first version of the questionnaire.

In each building, we surveyed a sample of students and employees before and after the intervention. All four samples were independent from each other (as identified by a self-generated code; in case of a person answering twice the questionnaire was deleted in one of the samples). We decided against a longitudinal design, because of the high fluctuation of student participants.

The final sample in this study contained 1269 cases. Nineteen cases were removed prior to analysis because of the lack of data in most of the items. There were 586 females and 645 males, and 38 participants who did not specify their gender. The majority of participants, 87.1%, were students, 12.3% were employees of NTNU or other private companies sharing the same building, and 0.6% were visitors. Because of a large number of student participants, about 70% of all cases were in the age group between 20 and 25 years old. Of the participants, 48% came to campus 5 days per week and more, about 16% came 4 days per week, 11.5% came 3 days per week, 13.4% came 2 days per week and 8.3% came to the campus 1 day per week.

In Table 1, the sample is described in terms of different groups (before/after intervention, experimental/control group, status of student/employee, gender).

Table 1. Participant information by groups.

			Before intervention (%)	**After intervention** (%)
Control group	*Gender*	Female	111 (55.22%)	219 (53.28%)
		Male	90 (44.78%)	192 (46.72)
		Total	201	411
	Status	Student	147 (70.33%)	402 (93.49%)
		Employee	62 (29.67%)	28 (6.51%)
		Total	209	430
Experimental group	*Gender*	Female	85 (37.12%)	171 (43.85%)
		Male	144 (62.88%)	219 (56.15%)
		Total	229	490
	Status	Student	198 (85.71%)	358 (91.56%)
		Employee	33 (14.29%)	33 (8.44%)
		Total	231	391

2.3. Questionnaire Components and Measures

The main part of the questionnaire was built around the theoretical model presented in the introduction. The items in the questionnaire were adapted from previous research [37–40]. Please see Appendix A, Table A1 for a listing of the items used. Included items from the model related to attitudes, intentions, descriptive norms, personal norms, subjective norms, perceived behavioural control, awareness of needs, awareness of consequences, ascription of responsibility and habits. All variables for the psychological model were measured by two to four indicators. Items were presented as statements where participants declared to what extent they agree with each statement on a scale of 1 to 7. The number of indicators and the Cronbach's alpha for each variable are presented in Appendix A, Table A2. Results indicate that the alpha coefficient for most items listed have relatively high internal consistency. However, it is noted that for the variables related to norms, the alpha coefficients, although considered "acceptable" in most social science research situations, are somewhat lower than findings in conventional past literature.

Self-reported waste separation behaviour was measured by a series of questions asking participants about their current behaviour at home and at NTNU. Each question was divided into sub-questions according to different portions that can be recycled, such as paper/cardboard, plastic, glass, metal, food and dangerous waste. Participants reported in these self-rating items about how often they separate these items on a scale from 1 to 7, where 1 was never and 7 was always. We decided to include also recycling behavior at home to test for congruency between the two domains.

3. Results

The analyses in relation to the study questions were conducted in a structural equation modelling framework. Before performing structural equation modelling (SEM), the measurement model of latent variables was examined (see Appendix for the measurement models of latent variables) using the complete data set as well as four subgroups separately. Results of confirmatory factor analyses (CFA) with maximum likelihood (ML) estimation using Mplus (version 7) software indicate that the following indicators have rather low standardized loadings from the respective latent variables: three items formulated to measure recycling at home (i.e., b_hm_pp1, b_hm_fd1 and b_hm_dg1); two items formulated to measure recycling at the university (i.e., b_un_pp1 and b_un_fd1); and one item formulated to measure perceived behavioral control (i.e., pbc2). Please refer to Appendix A, Table A1 for the complete list of items. These items were thus removed from the measurement model. Moreover, according to modification indices, allowing correlations between two indicators of recycling habit at university (i.e., hb_un_3 and hb_un_4) improved model fit significantly. The statistical fit of the revised measurement model is acceptable [43], as shown in Table 2.

Table 2. Model fit statistics of revised measurement model.

	χ^2	df	*p*	RMSEA	CFI	TLI	SRMR
Complete sample (*n* = 1241)	1481.737	313	<0.0001	0.055	0.951	0.940	0.054
Control group before intervention (*n*= 201)	561.084	313	<0.0001	0.063	0.935	0.921	0.065
Control group after intervention (*n* = 425)	629.863	313	<0.0001	0.053	0.950	0.940	0.058
Experimental group before intervention (*n*= 219)	580.435	313	<0.0001	0.062	0.933	0.919	0.064
Experimental group after intervention (*n* = 396)	849.800	313	<0.0001	0.066	0.936	0.923	0.072

[1] n= sample size; χ2= chi-square test; df= degrees of freedom; p= p-value, ;RMSEA= root square mean error of approximation; CFI = comparative fit index: TLI= Tucker-Lewis index; SRMR= Standardized root mean square residual.

3.1. Test of the Structural Model for the Whole Sample

After establishment of an acceptable measurement model, the hypothesized structural model depicted in Figure 1 was tested for the complete sample using Mplus (Version 7) software. The maximum likelihood estimation method (ML) was employed. The fit indexes reveal good fit of the model [43], χ^2 (df = 324, n = 1241) = 1627.256, $p < 0.0001$; RMSEA = 0.057, 90% CI = 0.054–0.060; CFI = 0.945; TLI = 0.936; SRMR = 0.059. The model accounts for 43% of the variance in recycling at university and 78.4% of the variance in intention to recycle. As shown in Figure 2, all of the hypothesized structural relationships are positive and significant. This analysis answers the research question about the usefulness of a model based on the CADM to determine recycling behavior at the workplace.

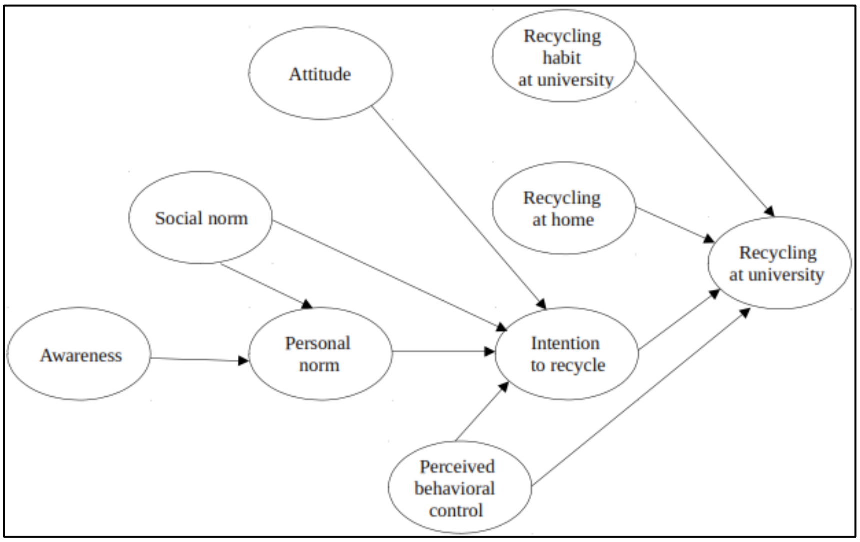

Figure 1. Hypothesized structural model.

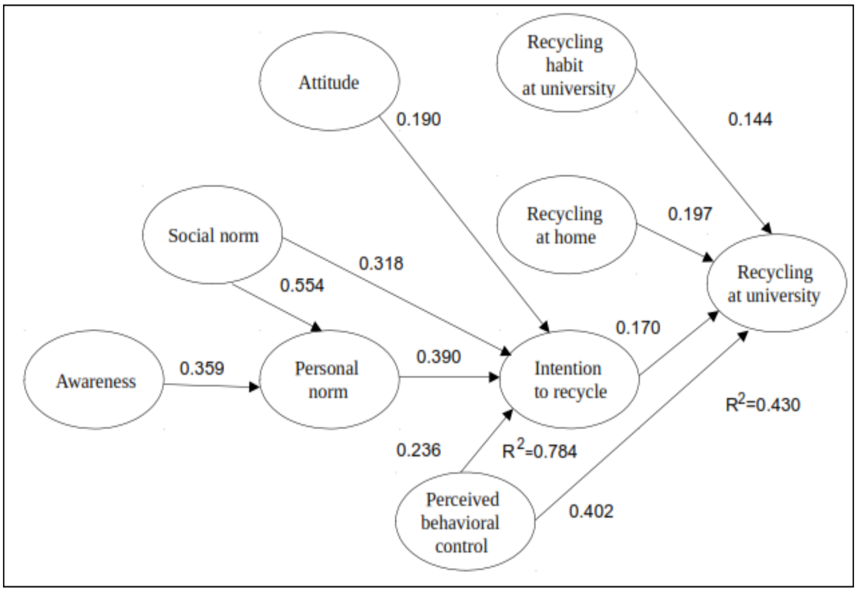

Figure 2. Structural equation model results.

3.2. Multiple Group Analyses of the Model

Subsequently, multiple group structural equation modeling (SEM) approach using maximum likelihood estimation method (ML) was used to compare subgroups on the causal model (see Figure 2). This was done to test, if after the intervention, the level of variables and potentially also their relation to each other changes. For this purpose, invariance of the measurement models in the groups needs to be established [44]. At the first step, a model without any invariance—a configural model (i.e., the same model in all groups, but all parameters to be estimated individually in all groups) was tested. Although the chi square for this model is statistically significant (i.e., χ^2 (df = 1296, n = 1241) = 2921.617, p < 0.0001), other fit indexes are acceptable (i.e., RMSEA = .064, 90% CI = 0.061–0.067; CFI = 0.932; TLI = 0.920; SRMR = 0.071). Thus, the model is considered to be a model that fits reasonably well [43]. This answers the question about changes in the model structure after the intervention. The model structure is unchanged.

As a second step, a model with invariant factor loadings—an equal loadings model (i.e., the same model with equal factor loadings in all groups, but all other parameters to be estimated individually in all groups) was tested. Although there are increases in values of χ^2 (i.e., χ^2 (df = 1353, n= 1241) = 3012.828, p < 0.0010) and a chi-square difference test showed significant difference between the configural model and the equal loadings model ($\Delta\chi^2$ = 3012.828 - 2921.617 = 91.211, df = 1353–1296 = 57, p = .002696), values of other fit indexes remain almost the same and acceptable (i.e., RMSEA = 0.063, 90% CI = 0.060–0.066; CFI = 0.930; TLI = 0.922; SRMR = 0.073). It thus appears that both models fit equally well statistically, so the parameters in question, i.e., factor loadings, can be fixed to be equal across groups and the model with equal loadings can be accepted as well.

After confirming that factor loadings are invariant across groups, as a third step, invariance of indicator intercepts—equal intercepts model (i.e., the same model with equal factor loadings and equal intercepts of indicators in all groups, but all other parameters to be estimated individually in all groups) was tested. The chi-square difference test showed that constraining indicator intercepts to equal across groups results in significantly worse fit than the equal loadings model ($\Delta\chi^2$ = 3188.258–3012.828 = 175.43, df = 1410–1353 = 57, p < 0.00001). However, values of other fit indexes indicate acceptable fit of the model to the data (i.e., RMSEA = 0.064, 90% CI = 0.061–0.067; CFI = 0.925; TLI = 0.920; SRMR = 0.075). Therefore, the results suggest that measurement invariance can be established, which is a prerequisite for testing further invariance of structural parameters of the model.

Since measurement invariance can be assumed, invariance of structural path coefficients—the equal paths model (i.e., the same model with measurement invariance and causal paths invariance, but other parameters to be estimated individually in all groups) was tested in the fourth step. The fit indexes show fit of the model remains acceptable, χ^2 (df = 1440, n = 1241) = 3224.596, $p < 0.0001$; RMSEA = 0.063, 90% CI = 0.060–0.066; CFI = 0.925; TLI = .921; SRMR = .076. A chi-square difference test between the equal paths model and the equal intercepts model reveals that there is no significant difference between them ($\Delta\chi^2$ = 3224.596–3188.258 = 36.338, df = 1440–1410 = 30, p = 0.197219). Therefore, the equal paths model can also be accepted. This implies that the casual paths in the model are no different across the subgroups, which answers the research question about possible changes in the relation between model variables. After the intervention, the relation between model variables remains unchanged. Consequently, the subgroups are compared on factor means and intercepts of latent variables. To this purpose, as a fifth step factor means and intercepts of latent variables across the subgroups before intervention (i.e., control group before intervention and experimental group before intervention) are constrained as equal at first by referring to the results of the equal paths model. The chi-square difference test showed constraining factor means and intercepts equal across the control group before intervention and the experimental group before intervention does not worsen the model fit compared to the equal paths model ($\Delta\chi^2$ = 3234.728–3224.596 = 10.132, df = 1449–1440 = 9, p = 0.339905). Values of other fit indexes remain almost the same and acceptable (i.e., RMSEA = 0.063, 90% CI = 0.060–0.066; CFI = 0.925; TLI = 0.922; SRMR = 0.076). This means that the two groups (control and experimental) were not different in the mean level of the model variables before the intervention.

As a sixth step, factor means and intercepts of latent variables for the control group after intervention are further constrained to be equal to the subgroups before intervention. The chi-square difference test between this model and the previous model at the fifth step reveals that there is significant difference between them ($\Delta\chi^2$ = 3306.994 − 3234.728 = 72.266, df = 1458 − 1449 = 9, $p < 0.00001$). Other model fit indexes also indicate worsening fit of this model to the data, χ^2 (df = 1458, n = 1241) = 3306.994, $p < 0.0001$; RMSEA = 0.064, 90% CI = 0.061–0.067; CFI = 0.922; TLI = 0.919; SRMR = 0.078. Therefore, the larger model, i.e., the model at the fifth step, appears to be a more reasonable model than the model at the sixth step. This means that the control group and the experimental group were different in the means in at least some variables after the intervention.

As a final step, factor means and intercepts of latent variables are constrained to be equal across all subgroups. The chi-square difference test and model fit indexes indicate this further constrained model results in a significantly worse fit than the model at the sixth step ($\Delta\chi^2$ = 3426.332 – 3306.994 = 119.338, df = 1467 – 1458 = 9, $p < 0.00001$; RMSEA = 0.066, 90% CI = 0.063–0.069; CFI = 0.918; TLI = 0.915; SRMR = 0.089). This result implies factor means and intercepts are significantly different between subgroups, and therefore invariance of factor means and intercepts across all subgroups cannot be claimed. Table 3 presents the estimated regression weights of complete model and Table 4 shows the difference in factor means and intercepts between the subgroups before intervention and the subgroups after intervention as the model at the fifth step appears to be an acceptable model. The results indicate that the control group after intervention has significantly lower mean scores on perceived behavioral control and recycling habits at the university than any other groups. In contrast, the experimental group after intervention has significantly higher mean scores on social norm, perceived behavioral control and recycling habits at the university than any other group. Moreover, the subgroups after intervention have significantly lower mean scores on intention to recycle while reporting significantly higher mean scores on recycling frequency at university than the subgroups before intervention. Finally, the results present mean differences in some central variables, but no significant changes in the model structure (i.e., same regression weights). As findings indicated similar relationships among latent variables, meaning equal path coefficients among all four groups, possible differences among the four groups are therefore further investigated by looking into latent variables means. Please refer to Figure 3, which presents the mean differences in the key variables where there is a difference including CIs.

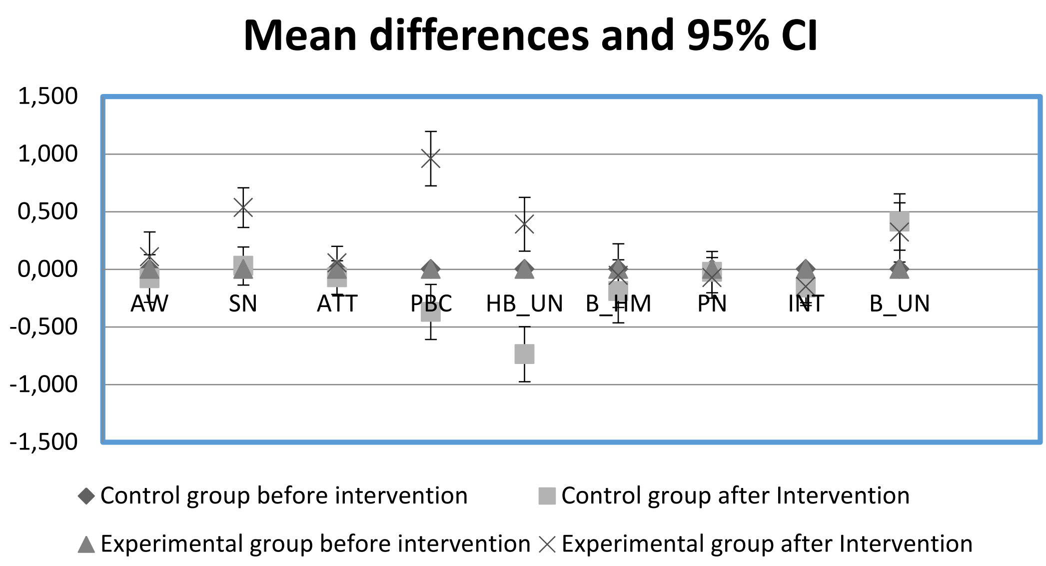

Figure 3. Mean differences in key variables.

Table 3. Estimated regression weights of complete model (n = 1241).

	B	SE	p	β		B	SE	p	β	R^2
Measurement part					**Causal paths**					
AW → an1	0.979	0.028	<0.0001	0.827	AW → PN	0.381	0.031	<0.0001	0.359	0.602
AW → an2	0.976	0.027	<0.0001	0.846	SN → PN	0.780	0.049	<0.0001	0.554	
AW → ac1	1.000			0.856	ATT → INT	0.296	0.040	<0.0001	0.190	0.784
AW → ac2	0.820	0.027	<0.0001	0.759	SN → INT	0.431	0.066	<0.0001	0.318	
PN → pn1	1.000			0.887	PN → INT	0.376	0.037	<0.0001	0.390	
PN → pn2	0.947	0.027	<0.0001	0.856	PBC → INT	0.206	0.029	<0.0001	0.236	
SN → dn1	0.894	0.041	<0.0001	0.678	HB_UN → B_UN	0.175	0.041	<0.0001	0.144	0.430
SN → dn2	1.000			0.778	B_HM → B_UN	0.221	0.032	<0.0001	0.197	
SN → sn1	0.984	0.048	<0.0001	0.649	INT → B_UN	0.241	0.056	<0.0001	0.170	
SN → sn2	0.990	0.047	<.0001	0.635	PBC → B_UN	0.497	0.048	<0.0001	0.402	
ATT → att1	1.000			0.843	Correlations of exogenous latent variables					
ATT → att2	1.214	0.046	<0.0001	0.830	AW ↔ SN	0.682	0.061	<.0001	0.417	
ATT → att3	0.869	0.046	<0.0001	0.563	AW ↔ ATT	0.707	0.054	<.0001	0.495	
PBC → pbc1	1.000			0.920	AW ↔ PBC	0.377	0.083	<.0001	0.149	
PBC → pbc3	0.923	0.027	<0.0001	0.841	AW ↔ HB_UN	0.752	0.083	<.0001	0.291	
INT → int1	1.000			0.837	AW ↔ B_HM	0.729	0.094	<.0001	0.260	
INT → int2	0.991	0.029	<0.0001	0.861	SN ↔ ATT	0.338	0.040	<.0001	0.313	
HB_UN → hb_un_1	1.007	0.014	<0.0001	0.940	SN ↔ PBC	1.208	0.082	<.0001	0.631	
HB_UN → hb_un_2	1.000			0.967	SN ↔ HB_UN	1.209	0.078	<.0001	0.620	
HB_UN → hb_un_3	0.942	0.015	<0.0001	0.915	SN ↔ B_HM	0.449	0.073	<.0001	0.212	
HB_UN → hb_un_4	0.917	0.016	<0.0001	0.892	ATT ↔ PBC	0.118	0.056	0.035	0.070	
hb_un_3 ↔ hb_un_4	0.262	0.024	<0.0001	0.438	ATT ↔ HB_UN	0.335	0.056	<.0001	0.197	
B_HM → b_hm_pl1	0.550	0.033	<0.0001	0.497	ATT ↔ B_HM	0.439	0.064	<.0001	0.237	
B_HM → b_hm_gl1	0.818	0.033	<0.0001	0.818	PBC ↔ HB_UN	1.745	0.108	<.0001	0.576	
B_HM → b_hm_mt1	1.000			0.900	PBC ↔ B_HM	−0.234	0.107	0.030	−0.071	
B_UN → b_un_pl1	0.626	0.025	<0.0001	0.621	HB_UN ↔ B_HM	0.171	0.105	0.106	0.051	
B_UN → b_un_gl1	1.000			0.924						
B_UN → b_un_mt1	0.946	0.020	<0.0001	0.899						
B_UN → b_un_dg1	0.821	0.028	<0.0001	0.689						

B = unstandardized regression coefficients; SE = standardized error; p = two-tailed p-value; β = standardized regression coefficients; R^2 = explained variance.

Table 4. Regression weights, factor means and intercepts of latent variables of multiple group analyses.

	Control Group before Intervention				**Experimental Group before Intervention**			
				Regression weights				
	B	SE	*p*	B	B	SE	*p*	β
AW → PN	0.379	0.031	<0.0001	0.346	#	#	#	0.347
SN → PN	0.777	0.049	<0.0001	0.570	#	#	#	0.512
ATT → INT	0.275	0.038	<0.0001	0.177	#	#	#	0.195
SN → INT	0.419	0.064	<0.0001	0.328	#	#	#	0.280
PN → INT	0.395	0.037	<0.0001	0.422	#	#	#	0.400
PBC → INT	0.207	0.029	<0.0001	0.246	#	#	#	0.215
HB_UN → B_UN	0.191	0.041	<0.0001	0.158	#	#	#	0.155
B_HM → B_UN	0.224	0.032	<0.0001	0.191	#	#	#	0.193
INT → B_UN	0.228	0.056	<0.0001	0.162	#	#	#	0.163
PBC → B_UN	0.501	0.050	<0.0001	0.422	#	#	#	0.372
				Means and intercepts of latent variables				
	M	SE	*p*	95% CI	M	SE	*p*	95% CI
AW	0.000	0.000			#	#		
SN	0.000	0.000			#	#		
ATT	0.000	0.000			#	#		
PBC	0.000	0.000			#	#		
HB_UN	0.000	0.000			#	#		
B_HM	0.000	0.000			#	#		
PN	0.000	0.000			#	#		
INT	0.000	0.000			#	#		
B_UN	0.000	0.000			#	#		
				Regression weights				
	B	SE	*p*	β	B	SE	*p*	β
AW → PN	#	#	#	0.359	#	#	#	0.383
SN → PN	#	#	#	0.555	#	#	#	0.552
ATT → INT	#	#	#	0.174	#	#	#	0.182
SN → INT	#	#	#	0.303	#	#	#	0.322

PN → INT	#	#	#	0.399	#	#	#	0.428
PBC → INT	#	#	#	0.227	#	#	#	0.222
HB_UN → B_UN	#	#	#	0.164	#	#	#	0.144
B_HM → B_UN	#	#	#	0.220	#	#	#	0.202
INT → B_UN	#	#	#	0.168	#	#	#	0.154
PBC → B_UN	#	#	#	0.405	#	#	#	0.364
Means and intercepts of exogenous latent variables								
	M	SE	*p*	95% CI	M	SE	*p*	95% CI
AW	−0.079	0.105	0.453	−0.285–0.127	0.107	0.111	0.334	−0.110–0.324
SN	0.029	0.084	0.731	−0.137–0.195	0.535	0.087	<0.001	0.364–0.707
ATT	−0.071	0.075	0.344	−0.217–0.076	0.054	0.075	0.473	−0.093–0.200
PBC	−0.371	0.122	0.002	−0.609–−0.132	0.960	0.120	<0.001	0.724–0.1.195
HB_UN	−0.737	0.122	<0.001	−0.976–−0.498	0.390	0.119	0.001	0.157–0.624
B_HM	−0.191	0.139	0.170	−0.465–0.082	−0.055	0.141	0.695	−0.332–0.222
PN	−0.023	0.091	0.800	−0.202–0.156	−0.074	0.090	0.410	−0.250–0.102
INT	−0.161	0.078	0.038	−0.314–−0.009	−0.151	0.070	0.032	−0.288–−0.013
B_UN	0.412	0.125	0.001	0.167–0.656	0.320	0.131	0.015	0.063–0.577

B = unstandardized regression coefficients; M= mean, SE = standardized error; *p* = two-tailed *p*-value; β = standardized regression coefficients; CI = confidence interval,

4. Discussion

The SEM results fulfill the expectations and fit into the theoretical construct of this study. This finding has significant implications for the use of rigorous theoretical frameworks such as the CADM model when attempting to understand waste separation behaviour. Results show that all the psychological determinants that were expected to be predictors of waste separation behaviour were significant. The model with the best fit presented provides a better understanding of how each of these psychological determinants mediates and affects waste separation behaviour at work—see Figure 2. The results indicate mean differences in some central variables, but present no changes in the model structure itself (same regression weights). This result implies that the intervention changes how people evaluate perceived behavioural control, intentions, and habits, for example, but, as expected, does not necessarily change their relationship to the other psychological variables. These findings further suggest that waste separation at work must go beyond technical aspects to include various key elements of sustainability (such as a sense of control and empowerment) to ensure success. Furthermore, the results indicate that understanding human behavior is vital in determining the performance and success of an integrated and effective recycling intervention strategy.

The control group post-intervention showed significantly lower mean scores on perceived behavioral control and recycling habits at the university than any other group. The significant observed changes could be accounted for by the design of the study—in particular, the sampling design. Given the nature and scope of the experiment, the groups sampled before the intervention and after the intervention were not the same people.

The experimental group scored higher on the scale measuring self-reported behaviour in the post-intervention study, which shows the effect of the intervention strategy.

The result implies that intervention designs and development should target people using the normative route with strategies such as social acceptance and normative influences, and influence the degrees of control a person has over waste separation behaviour. The interventions clearly had an impact on the experimental group's behaviour toward waste separation. Change in waste separation behaviour in the experimental group is clearly affected by stronger intentions to recycle after the intervention period. Intention as an immediate antecedent of behaviour is an integration of attitudes, subjective norms, and perceived behavioural control [26], with social norms resulting from individuals combining beliefs regarding the extent to which others want them to perform the behaviour [43]. In the present study, the results show that participants in the experimental group had increased feelings of social pressure in terms of waste separation at NTNU.

Personal norms, as a feeling of moral obligation and responsibility to perform a given behaviour [33], also increased for this group. The assumption that social and personal norms will change after the intervention period has been confirmed. This finding further indicates the need to target people's social and normative influences when designing interventions about waste separation at work.

The score for perceived behavioural control also increased in the post-intervention study. Participants felt they had stronger control over waste separation after the intervention period. Availability, accessibility, and situational conditions are the main aspects of perceived behavioural control [26]. The intervention strategy allowed people to access new waste stations at strategic points so they can handle their waste easily by separating paper, plastic, glass, metal, dangerous waste and residual wastes. Participants believed that they could perform the behaviour better after the intervention period since they had the ability to separate their waste and the waste stations were accessible and easy to find. They had the necessary information from the flyers, TV screens, informational emails and other sources about what to recycle and how. The presence of factors that may facilitate the behaviour, the ease of performing the behaviour, and the feeling of control over the performed behaviour are the main components of this psychological determinant [43]. A sense of being in control at work is important for waste separation behavioural change, and, therefore, the design and implementation of any interventions should focus on creating a sense of empowerment and control.

Results show that waste separation habits at NTNU increased after the intervention in the experimental group. Regularly repeated behaviour may become habitual, involuntary, and automatically determine future behaviour [44]. When students and employees had an opportunity to separate their waste on a daily basis, they acquired this behaviour as a habit, raising the score for habits at NTNU. In contrast, habits at home did not change: habits are not adapted behavioural patterns that are performed everywhere and every time, but are behaviours performed in rather stable conditions—in the same environment and under the same circumstances [45]. The results of this study show that attitudes had not changed after the intervention period and the scores for all of the groups are similar—possibly because people in general believe that waste separation is good and useful. Therefore, their attitudes toward waste separation at NTNU did not change after the intervention period.

Several limitations call for careful interpretation of the results. First, the intervention strategies were pre-designed by the NTNU's project group Klimafot avfall. Hence, no adjustment or input on the design of the interventions was possible. The project group decided on intervention strategies, and the questionnaire was designed according to the proposed interventions. The study was strictly limited to the implemented interventions at one of the chosen buildings (pre-chosen by the project group) at NTNU's campus. Second, because of time limitations, examination of long-term effects was not possible. Owing to the use of self-reporting methods, the possibility of biases should also be considered with respect to the reliability of the data, and self-reported recycling behaviour is known to be exaggerated [46]. People motivate their reasoning on the basis of positive information about themselves [47]; therefore, drawing on their knowledge about the positive effects of recycling, many can overestimate their actions. Future research in this area could be directed at understanding the long-term effect of intervention and communication strategies on recycling behaviour in workplaces. Future studies applying other geographical contexts and cross cultural studies would also be useful.

5. Conclusions

This study moves toward a better understanding of the mechanisms behind changing people's recycling behavior at work by mapping out which pathways and variables changes in recycling behavior as triggered by the interventions. This study investigated whether recycling behavior, as well as the level and relation of psychological determinants changed after structural interventions to increase waste separation were implemented and examined the direction of the change. Moreover, the study examined which psychological determinants were predicting intentions to recycle.

The results show that the implemented intervention strategies can be considered successful. First, there are significant differences in self-reported behaviour pre- and post-intervention in the experimental group, whereas no change can be found in the control group. The findings of this study show that the most important characteristics and predictors of the waste separation behaviour are intention, perceived behavioural control, habits, social norms, and personal norms. These relationships imply that, in order to increase waste separation, one needs to perceive possessing control over the performed behaviour. In addition, social and personal norms must be formed, but their influence is mediated by intention to perform the behaviour. These findings support the chosen conceptual framework and indicate that the CADM model, by providing a good description of the factors impacting recycling at the workplace, is a good fit with the data.

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Author Contributions: Christian A. Klöckner conceived the research framework and Christian A. Klöckner and Sunita Prugsamatz Ofstad conceived and designed the experiments on the basis of the interventions strategies implemented by the project group Klimafot avafall at the Norwegian University of Science and

Technology. Monika Tobolova performed the experiments; Alim Nayum, Christian A. Klöckner and Monika Tobolova analyzed the data; Sunita Prugsamatz Ofstad wrote the paper.

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Appendix A

Table A1. Indicators for the latent variables.

Indicators
AW: Awareness **(4 items; Cronbach's α = 0.89)**
an1: Refraining from separating my waste at NTNU is an important problem for the environment.
an2: It is really important to do something against environmental destruction caused by refraining from separating my waste when I am at NTNU.
ac1: When I refrain from separating my waste when I am at NTNU, I contribute to environmental problems in Trondheim.
ac2: If I separate my own waste at NTNU, I personally contribute to saving the environment
PN: Personal norm **(2 items; Cronbach's α = 0.86)**
pn1: Because of my principles, I feel personally obliged to separate my waste when I am at NTNU.
pn2: Based on values important to me, I feel obliged to separate my waste when I am at NTNU as best as possible.
SN: Social norm **(4 items; Cronbach's α = 0.79)**
dn1: Many people who are important to me separate their waste at their workplace or place of study.
dn2: My colleagues or fellow students at NTNU who are important to me, separate their waste when they are at NTNU.
sn1: People who are important to me try to influence me towards separating my waste when I am at NTNU.
sn2: I think many people who are important to me expect that I should separate my waste when I am at NTNU.
ATT: Attitude **(3 items; Cronbach's α = 0.77)**
For me, separating my waste when I am at NTNU, instead of throwing it all in the residual waste, would be…
att1*: good/bad
att2*: useful/useless,
att3*: unpleasant/pleasant.
PBC: Perceived behavioral control **(3 items; Cronbach's α = 0.77)**
pbc1: Separating my waste when I am at NTNU is easy for me.
pbc2: There are conditions that force me to refrain from waste separation when I am at NTNU.
pbc3: If I wanted to, I could easily separate my waste when I am at NTNU.
INT: Intention **(2 items; Cronbach's α = 0.84)**
int1: My intention to separate waste when I am at NTNU in next 7 days is strong.
int2: I plan to separate waste when I am at NTNU in the next 7 days.
HB_UN: Recycling habit at university **(4 items; Cronbach's α = 0.97)**
hb_un_1: Separating my waste at NTNU is something I do automatically.
hb_un_2: Separating my waste at NTNU is something I do without thinking.
hb_un_3: Separating my waste at NTNU is something I do without having to consciously remember.
hb_un_4: Separating my waste at NTNU is something I start doing before I realize I am doing it.
B_HM: Recycling at home **(6 items; Cronbach's α = 0.71)**
On the scale from 1 to 7, how often do you usually separate these waste fractions when you are at home?
b_hm_pp1: Paper/cupboard
b_hm_pl1: Plastic
b_hm_gl1: Glass
b_hm_mt1: Metal
b_hm_fd1: Food
b_hm_dg1: Dangerous waste (e.g., batteries)

B_UN: Recycling at university **(6 items; Cronbach's α = 0.84)**	
On a scale from 1 to 7, how often do you usually separate these waste fractions when you are at NTNU?	
b_un_pp1: Paper/cupboard	
b_un_pl1: Plastic	
b_un_gl1: Glass	
b_un_mt1: Metal	
b_un_fd1: Food waste	
b_un_dg1: Dangerous waste (e.g., batteries)	

* reverse coded.

Table A2. Number of indicators for the variables and Cronbach's α.

Variable	No. of Indicators	Cronbach's α
Attitude	3	0.77
Intention	2	0.84
Descriptive norms	2	0.68
Perceived behavioural control	3	0.77
Personal norms	2	0.86
Subjective norms	2	0.67
Ascription of responsibility	2	0.85
Awareness of needs	2	0.83
Awareness of consequences	2	0.79
Habits at home	4	0.92
Habits at NTNU	4	0.97

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