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Social-cognitive factors mediating intervention effects on handwashing: a longitudinal study

Nadja Contzen[1] · **Jennifer Inauen**[2]

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Abstract Handwashing with soap effectively prevents diarrhoea, a leading cause of death in infants. Theory-based interventions are expected to promote handwashing more successfully than standard approaches. The present article investigates the underlying change processes of theory-based handwashing interventions. A nonrandomised field study compared a standard approach to two theory-based interventions that were tailored to the target population, the inhabitants of four villages in southern Ethiopia ($N = 408$). Data were collected before and after interventions by structured interviews and analysed by mediation analysis. In comparison to the standard approach (i.e., education only), education with public commitment and reminder was slightly more effective in changing social-cognitive factors and handwashing. Education with an infrastructure promotion and reminder was most effective in promoting handwashing through enhancing social-cognitive factors. The results confirm the relevance of testing interventions' underlying change processes.

Keywords Handwashing interventions · Diarrhoea · Social-cognitive factors · Behaviour change · Mediation analysis · RANAS approach

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✉ Nadja Contzen
nadja.contzen@eawag.ch

[1] Environmental and Health Psychology Group, Department of Environmental Social Sciences, Eawag: Swiss Federal Institute of Aquatic Science and Technology, Überlandstrasse 133, 8600 Dübendorf, Switzerland

[2] Chair of Applied Social Psychology, Department of Psychology, University of Zurich, Zurich, Switzerland

Introduction

Diarrhoea is a leading cause of death in children under the age of five in Ethiopia (World Health Organization Regional Office for Africa, 2010) and globally (Black et al., 2010). The single most effective preventive measure against childhood diarrhoea is primary caregivers' handwashing with soap at key times, namely before contact with food and after potential contact with stool (Cairncross et al., 2010; for the distinction between food- and stool-related handwashing, see also Contzen & Mosler, 2013). In spite of its preventive power, handwashing is uncommon in Ethiopia and in most developing countries (Curtis et al., 2009; Federal Ministry of Health Ethiopia, 2011), and also remains a challenge in developed countries, e.g. in health care settings (Bittner et al., 2002; Miller et al., 2011; Pessoa-Silva et al., 2007) and pandemics (Miller et al., 2011; Updegraff et al., 2011). Core tasks of health promoting agencies therefore include developing and implementing handwashing programs. However, their efficacy is often mixed (Aboud & Singla, 2012; Naikoba & Hayward, 2001; Wilson et al., 2011). To increase the effectiveness of health behaviour change interventions, scholars advocate using behavioural theories to inform them (Aboud & Singla, 2012; Al-Tawfiq & Pittet, 2013; Michie & Johnston, 2012). As each theory identifies only a subset of potentially relevant behavioural determinants to intervene on, maximal effectiveness is expected when multiple theories are considered (Abraham, 2012; Lippke & Ziegelmann, 2008). In addition to assessing the efficacy of such theory-based interventions, it is essential to test their underlying change processes (Michie & Abraham, 2004). Therewith, we can extend the still limited evidence base of strategies to change specific behavioural determinants and also better understand *why* a

strategy was (in)effective, which helps to improve it (Abraham, 2012; Lippke & Ziegelmann, 2008).

The present article builds on work from a larger research project that tested two handwashing interventions in four kebeles (smallest administrative units of Ethiopia) in the Borena Zone, southern Ethiopia. Both interventions were selected in accordance with the results of a baseline study in the four kebeles (Contzen et al., 2015) that applied the RANAS (Risk, Attitudes, Norms, Abilities, Self-regulation) approach, a multi-theoretical framework to design water, sanitation and hygiene (WaSH) interventions in developing countries (Mosler, 2012). The main idea of the RANAS approach is to tailor interventions to a population through (1) quantitative identification of the social-cognitive factors that determine the key behaviour in the target population and (2) selecting behaviour change techniques (BCTs) expected to target exactly these factors for intervention development. The social-cognitive factors considered by the RANAS approach are those specified in well-known theories of behaviour change, such as the health belief model (Rosenstock, 1974), protection motivation theory (Rogers, 1975), social cognitive theory (Bandura, 1977), the theory of planned behaviour (Fishbein & Ajzen, 2010), and the health action process approach (Schwarzer, 2008). A detailed description of the RANAS approach's application in this research project including a detailed presentation of the baseline results and the intervention selection is presented elsewhere (Contzen et al., 2015). In short, Contzen et al. (2015) identified the following determinants of handwashing in the four kebeles in southern Ethiopia: (1) the descriptive norm, i.e. behaviours typically practiced by others; (2) the injunctive norm, i.e. behaviours typically approved or disapproved by others; (3) impediments, i.e. anticipated barriers and distractions to a behaviour; (4) forgetting, i.e. forgetting to execute a behaviour at a specific time/in a specific situation; and (5) the inconvenience of the present handwashing technique. To promote handwashing in the four kebeles through theory-based population-tailored interventions, Contzen et al. (2015) selected three BCTs assumed to target these five factors (Mosler, 2012): public commitment, facilitating resources, and reminders. Because testing the effects of these three BCTs with a $2 \times 2 \times 2$ experimental design was beyond the scope of the research project, the BCTs were combined into two interventions: Intervention 1 was a public commitment with reminder, and intervention 2 was an infrastructure-promotion comprising facilitating resources (i.e. construction of handwashing stations) with reminder. Contzen et al. (2015) tested the interventions' main effects in a full factorial design and found that changes in handwashing were significantly more positive in all intervention arms compared to the control arm that received a standard education intervention.[1] This result emphasizes the superiority of theory-based population-tailored interventions. However, it is unclear *why* these interventions were more effective than the standard education intervention. To address this research question, the aim of the present article was to investigate the interventions' underlying change processes.[2] The theorized social-cognitive mechanisms of the two interventions are described in the following.

Mechanisms of change to promote handwashing with soap

Making a commitment, defined as "an oral or written pledge or promise to change behaviour" (Abrahamse et al., 2005, p. 275), given to oneself or the public, is a widely used BCT (Lokhorst et al., 2013). The RANAS model (Mosler, 2012) links public commitment to an increase in commitment strength (strength of commitment towards practicing a behaviour) and the injunctive norm (see also Abrahamse et al., 2005; Lokhorst et al., 2013). Previous research supports these effects (Inauen et al., 2013; Kraemer & Mosler, 2012). In addition, according to the RANAS model, seeing others commit should affect the descriptive norm (Mosler, 2012). Provided the public commitment is delivered as a sign, it should also serve as a reminder, and thus lower forgetting (Mosler, 2012; Tobias, 2009).

According to the RANAS model (Mosler, 2012) adding infrastructure (here a handwashing station) should decrease impediments by making resources (here water and soap) easily accessible, and lessen forgetting by serving as a reminder (Devine & Koita, 2010; Luby et al., 2009; Scott et al., 2007). Previous research has also shown that a handwashing station facilitates using a handwashing technique that is quick and easy because of the ready availability of water and soap, and because both hands are free for handwashing (Biran, 2011; Curtis et al., 2009; tippytap.org, n.d.). Therefore, using the handwashing infrastructure should allow mastery experience of *regular* handwashing which, in turn, should lead to increased motivational self-efficacy—the belief in one's capability to initiate and execute a behaviour—and volitional self-efficacy—the belief in one's capability to maintain the behaviour and to recover from relapse (Bandura, 1998; Mosler, 2012; Schwarzer, 2008). Further, the energy, time, and costs publicly invested in constructing a handwashing station for the household might strengthen households'

[1] For the interventions' main effects, which are not reported in the present article, please refer to Contzen et al. (2015).

[2] Testing the processes that underlay behaviour change (Michie & Abraham, 2004) is a vital contribution that could not have been integrated into the article by Contzen et al. (2015).

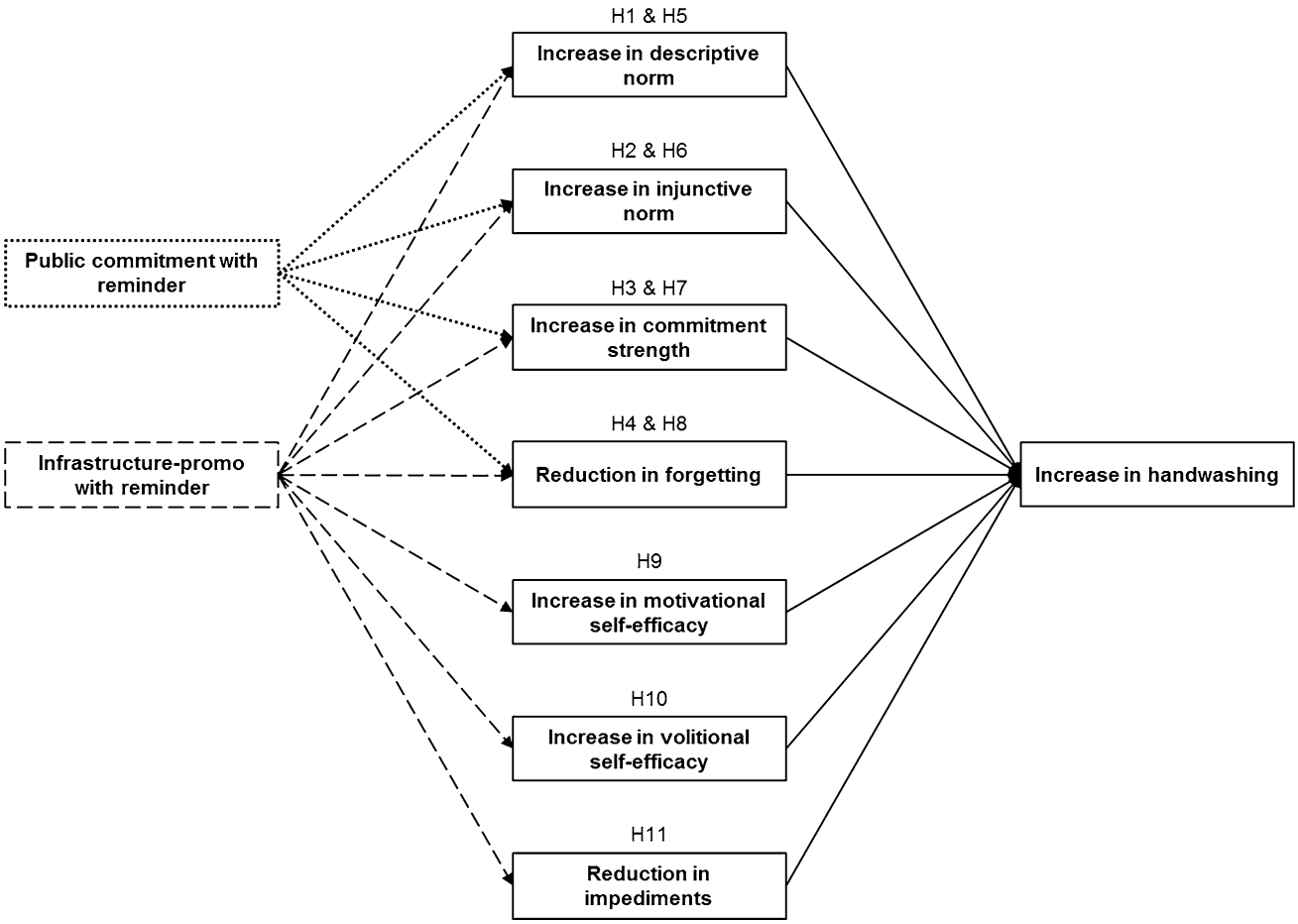

Fig. 1 Assumed underlying change mechanisms. *Dotted lines* represent assumed effects of public commitment with reminder on social-cognitive factors. *Dashed lines* represent assumed effects of infrastructure-promotion with reminder on social-cognitive factors. *Solid lines* represent assumed effects of social-cognitive factors on handwashing

commitment to using it, and elevate others' expectations, increasing the injunctive norm. Finally, given that handwashing stations are constructed outside the house, using the handwashing stations should transform the traditionally privately-performed handwashing behaviour into a publically-performed one, which was expected to enhance the descriptive norm (Curtis et al., 2009; Scott et al., 2007).

The aim of this article was to test the underlying behaviour change processes of the two interventions independently and combined. That is, the article focused on the indirect effects of the two interventions on behaviour change via changes in social-cognitive factors. In line with the theoretical assumptions and previous studies described above, the following indirect effects were assumed (see Fig. 1): compared to a control group, the public commitment with reminder intervention increases behaviour via increasing the descriptive norm (H1); increasing the injunctive norm (H2); increasing commitment strength (H3); and reducing forgetting (H4). For the infrastructure-promotion with reminder intervention, the same and additional indirect effects were expected: compared to a control group, the intervention increases behaviour via increasing the descriptive norm (H5); increasing the injunctive norm (H6); increasing commitment strength (H7); reducing forgetting (H8); increasing the motivational and volitional self-efficacy (H9 & H10); and reducing perceived impediments (H11).

Methods

The above hypotheses were tested with data collected in a larger research project (cf. Contzen et al., 2015). The project represents a nonrandomised controlled trial with a pre-post-test and a full factorial design with four arms (for a flow chart of the trial, see Contzen et al., 2015). An education intervention was implemented in all arms, including the control group. This follows the idea to apply a strong comparison group that incorporates some intervention components instead of a pure control or contact

control condition to test the interventions of interest more rigorously (Williams, 2010). Arm 1, the control group, received the education intervention only (Educ); arm 2 received education and public commitment with reminder (Educ+PubRem); arm 3 received education and the infrastructure-promotion with reminder (Educ+InfrRem); and arm 4 received the full combination of interventions, i.e. education, public commitment with reminder and infrastructure-promotion with reminder (Educ+PubRem+InfrRem). Reporting followed the Transparent Reporting of Evaluations with Nonrandomized Designs (TREND) statement (Des Jarlais et al., 2004).

Research area

The research project was conducted from February 2012 to March 2013 in the Borena Zone in southern Ethiopia. The Borena Zone is a semi-arid region recurrently hit by droughts causing food insecurity and famine (Debsu, 2013). Handwashing interventions have been implemented in the region since 2006 as part of the repeated drought emergency responses.

Clusters and participants

The research project was implemented in cooperation with a local NGO who was working in 28 kebeles across four Borena departments. However, the present project was limited to only four of these kebeles.[3] First, security issues and logistical considerations restricted data collection to two out of the four departments. Further, across these two departments the local NGO was active in twelve kebeles but ongoing hygiene interventions by concurrent NGOs or limited accessibility led to the exclusion of eight kebeles. The remaining four kebeles were assigned to arms 1–4. The budget of this research project was constrained. Therefore, to minimize time and labour for intervention implementation and thus project costs, instead of randomly assigning kebeles to intervention arms, the first author and NGO representatives allocated the kebele that was most difficult to access to arm 1 (control arm) in which least activities had to be implemented and the kebele that was easiest accessible to arm 4 (full intervention arm) in which most activities had to be implemented. The remaining two kebeles were randomly assigned to arms 2 and 3. The number of households per kebele ranged between 200 and 800, grouped in approximately 30 hamlets. Only those hamlets that were reachable by car or a maximum 20-min walk were included in the research project. Within each hamlet, households were randomly selected by the random-route method (Hoffmeyer-Zlotnik, 2003).

The eligibility criterion for participation was being a primary caregiver (usually a woman) of children under the age of five. Primary caregivers were targeted because they are responsible for childcare and cooking, and thus, have the highest chance of transmitting diarrhea-causing pathogens. In addition, they may act as models and accordingly influence the family's hygiene behaviour.

Sample size estimation with G*Power 3.1 (Faul et al., 2009) suggested a survey of 400 households to detect a medium effect at the Type I error probability of 0.05 and a statistical power of 0.95. Allowing an attrition rate of 20 %, the project aimed to interview 500 primary caregivers. In total, only 462 baseline interviews were conducted due to difficulties in data collection. Of these, 23 did not receive the allocated interventions (5 %) and 31 were not available for follow-up (7 %). Thus, in total, 408 primary caregivers were interviewed at both times, had received the allocated interventions, and were subsequently analysed.

As expected, all interviewees were women. Their mean age was 35.52 years ($SD = 14.19$). The vast majority of the respondents had never attended school ($n = 396$, 97.1 %) and were illiterate ($n = 399$, 97.8 %). On average, project households comprised one child under the age of five ($M = 1.34$, $SD = 0.52$). The mean income per person, per day was US $0.17 ($SD = 0.19$), which was far below the poverty line of US $1.25 (Ravallion et al., 2009).

Data collection method

Data were collected at baseline (6 months prior to interventions; these data were used for intervention development briefly presented in the Introduction; for more details see Contzen et al., 2015) and follow-up (approximately 3 months after interventions) by 1-h-long, structured, face-to-face interviews in Afan Oromo at the respondents' homes. The interviews were conducted by teams of 10 (baseline) and 14 (follow-up) local students and social workers of which two were female. The team was trained in interviewing techniques in a 4-day workshop, and supervised during data collection by researchers and the local collaborator.

Measures

A structured questionnaire was developed for this research project; it covered self-reported handwashing, social-cognitive factors, and socio-demographic characteristics. Most of the questionnaire items were derived from the RANAS approach (Mosler, 2012) and previous studies (Contzen & Mosler, 2013; Huber et al., 2012; Inauen & Mosler, 2013). Some of the factors of the RANAS were measured both

[3] Information on the socio-economic and socio-demographic characteristics of the excluded kebeles and thus on differences between excluded and included kebeles is not available.

regarding stool- and food-related handwashing separately (see below). To keep the length of the interview acceptable it was therefore unfeasible to apply multi-item scales for each factor. According to the C-OAR-SE method, however, to validly measure a construct one does not require a multi-item scale but rather a measure with maximal content validity (Rossiter, 2011). In line with this approach, mainly single-item measures were applied for which the primary selection criterion was maximal content validity (i.e. semantic correspondence of the construct and the measure) while taking into account the local context. To capture multidimensional constructs, multi-item measures were used, that is for each dimension of a multidimensional construct one item was included in the questionnaire. During data processing, items measuring a multidimensional construct were combined to a composite measure. With two exceptions (see below), the response options were Likert scales (5-point for unipolar items and 9-point for bipolar items), which were later transformed into a value range of 0–1 (or −1 to 1 for bipolar items) to facilitate interpretation of the unstandardized regression coefficients. The questionnaire was prepared in English, translated into Afan Oromo, and re-translated into English to ensure the quality of the translation. Its applicability was verified in a pre-test of $N = 20$. The following presents example questions for each construct and internal consistencies (baseline/follow-up).

Stool- and food-related handwashing

Self-reported handwashing was measured by eight items in the following format: 'In general, how often do you wash your hands with soap before eating/after going for defecation?' (0 = almost never to 4 = almost always). Self-reported handwashing has been criticised to be biased by socially desirable responding. However, it may still be seen as valid outcome measure as it has been found to be associated with critical health effects, such as child diarrhoea (e.g. Luby, et al., 2011b; for more details see the "Discussion"). Surveyed key times were those usually promoted in handwashing interventions focusing on diarrhoea prevention (Luby, et al., 2011a), that is after defecation, wiping a child's bottom or other kinds of contact with stool (stool-related handwashing, SRH); before eating, preparing food, breastfeeding or feeding a child, and handling drinking water (food-related handwashing, FRH). The finding from previous research that SRH and FRH are statistically separable (and partly explained by different behavioural factors; Contzen & Mosler, 2013), was verified in the present project by confirmatory factor analysis. Internal consistencies were satisfactory (Cronbach's α SRH [baseline/follow-up] = .88/.90, Cronbach's α FRH [baseline/follow-up] = .89/.91).

Social-cognitive factors

Descriptive norm Stool- and food-related descriptive norms were measured with one item each. People were asked, 'How many people of your community wash hands with water and soap *before handling food (bhf)/after contact with stool (acws)?*'[4] (0 = *almost nobody* to 4 = *almost all of them*).

Injunctive norm Two items for SRH and two items for FRH were applied. Respondents were asked, for example, 'Do people who are important to you rather think you should or you should not wash your hands with soap and water *bhf/acws?*' (-4 = *nearly all think I should not* to 4 = *nearly all think I should*; Cronbach's α stool [baseline/follow-up] = .78/.55; Cronbach's α food [baseline/follow-up] = .77/.58).

Forgetting To measure the construct, people were asked to specify the number of times within the last 24 h they intended to wash their hands with soap and water and then forgot to do so (natural numbers used as answer scale).

Commitment strength Stool- and food-related commitment strengths were measured with one item each, namely, 'Do you feel committed to wash your hands with soap and water *bhf/acws*?' (0 = *not committed* to 4 = *very committed*).

Motivational self-efficacy This was assessed with one item each for SRH and FRH. People were asked whether they felt able to always wash hands with soap and water *bhf/acws* (0 = *not able* to 4 = *very able*).

Volitional self-efficacy Volitional self-efficacy was measured with four items, such as 'How confident are you that you can wash hands with soap and water even if urgent tasks arise interfering with handwashing?' (0 = *not confident* to 4 = *very confident*; Cronbach's α [baseline/follow-up] = .78/.73).

Impediments Three items were used to assess impediments. People were asked, for example, 'When you think

[4] During the interview respondents were informed by the interviewer that handwashing before handling food means handwashing before preparing food, eating, feeding or breastfeeding a child or handling drinking water, and that handwashing after contact with stool means handwashing after defecation, wiping a child's bottom and other contact with stool.

about the last week, how often did it happen that there was no water for handwashing?' and to specify the number of times (natural numbers used as answer scales; Cronbach's α [baseline/follow-up] = .74/.61).

Changes in behaviour and social-cognitive factors

To examine changes in handwashing and social-cognitive factors, baseline values were subtracted from the follow-up values for each individual (van Breukelen, 2013). In non-randomised trials such as the present study using change scores as dependent variable should be preferred over ANCOVA as the latter tends to deliver biased results (Jamieson, 2004; van Breukelen, 2013). These change scores inform about the extent and direction of change but not about the absolute value in cognition or in behaviour.

Interventions and implementation design

The interventions were delivered in community meetings from October 2012 to January 2013, by one female and nine male health promoters employed and supervised by the local NGO. Twenty to thirty primary caregivers of one or several hamlets in a kebele were invited to each meeting through home visits that explained the interventions' objective and content. To cover all households in a kebele and depending on the number of households per kebele, in each kebele and for each intervention between 12 and 20 meetings were conducted. The interventions were approved by the kebele leaders and elders who explicitly endorsed participation. All interventions were appraised positively by the communities and participation rates were high (95 %). The interventions are described in brief below; detailed descriptions can be found in the Electronic Supplementary Materials.

Interventions

Education intervention (Educ) As an education intervention, an f-diagram exercise was implemented. The f-diagram is a graph illustrating the transmission routes of diarrhoea, which is regularly used by NGOs as a hygiene behaviour change tool (David et al., 2009; Global WASH Cluster, 2011). The tool was applied as a group sorting task at a 1-h community meeting.

Public commitment intervention with reminder (PubRem) Two-hour community meetings were organized during which first the education intervention was implemented as part of the commitment meeting and second primary caregivers were asked to give oral statements of their commitment (Inauen et al., 2013). A commitment sign, a headscarf to be worn, and a commitment certificate to be pinned up were handed out.

Infrastructure-promotion intervention with reminder (InfrRem) Households were invited and motivated during home visits to construct a handwashing station for their household. Right after a 1-h community meeting which demonstrated the construction, the promoters, who also assisted in the construction, distributed jerry cans required for the handwashing station.

Intervention fidelity

To maximise intervention fidelity, all interventions were specified in detail by written instructions provided by the first author. The promoters were trained in a 2-day workshop outlined by the first author and held by supervisors of the local NGO, a local collaborator of the researchers, and representatives of a collaborating international NGO. The supervisors, supported by the local collaborator, assisted the promoters throughout the interventions and ensured the quality through field visits and by revising delivery documentation (i.e. monitoring and attendance forms). No protocol deviations were noted, with one exception. There are indications that the purpose of the public commitment sign (i.e., the scarf) was misunderstood. The researchers' main idea behind the sign was that people continuously expressed their commitment to the community by wearing the scarf, which should have constantly triggered social norms and commitment strength. Instead, it was only conveyed to the communities that the scarf served as a reminder.[5] Further, for the Educ+PubRem arm, there is anecdotal evidence suggesting that, in some cases, the purpose of the scarf was overridden. Some respondents said that they were told to wear the scarf to be given a lift, or simply to wear the scarf when people from outside visited the kebele.

Data analysis method

The interventions' effects on change scores in behaviour through change scores in social-cognitive factors were analysed (van Breukelen, 2013). All analyses were run separately for SRH and FRH using IBM SPSS Statistics 22, and using Bootstrapping with 10,000 re-samples for estimating confidence intervals. As directional hypotheses were tested, 90 % confidence intervals were estimated. Hypotheses H1 to H11 were tested by calculating simple mediation models according to Hayes and Preacher (2013) and using the 'MEDIATE' macro. In each model, Educ-

[5] That the scarf would serve as a reminder was assumed to be an additional effect.

plus combinations were represented by three dummy variables with Educ-only as the reference group. For each social-cognitive factor a separate model was run, that is altogether seven models were calculated for SRH and FRH each. As these models referred to separate null hypotheses and not to a global null hypothesis, no control for the familywise error rate was necessary (Bender & Lange, 2001). All assumptions for linear regression analysis were met. Further, to investigate the combined importance of the mediators, multiple mediation models were computed using the 'INDIRECT' macro (Preacher & Hayes, 2008). Separate models were run to test for each intervention dummy variable while the other two were entered as covariates (Preacher & Hayes, 2008), that is three models were computed for SRH and FRH each. This approach was preferred to using the 'MEDIATE' macro because only the 'INDIRECT' macro provides estimates for the total and total indirect effects of the independent variable (here the Educ-plus combinations). As all three dummy variables were entered in each model (one as the independent variable and the other two as covariates) their familywise error was already considered and no control for multiple testing was necessary. Again, all assumptions were met. In simple and multiple mediation models, the *z*-standardized values of mediators and dependent variables were applied so as to receive partially standardized effects (Hayes, 2013).

Results

Table 1 displays the means, standard deviations and intercorrelations of changes in social-cognitive factors and in behaviour. Results from simple mediations are summarized in Tables 2 and 3. Starting with Educ+PubRem compared to Educ, results differed slightly with regard to SRH and FRH. While the descriptive norm was significantly enhanced by Educ+PubRem, it significantly mediated only the intervention's effect on SRH but not on FRH. Therewith, H1 was only partly supported. Neither the injunctive norm, commitment strength nor forgetting was significantly affected by Educ+PubRem and none of these social-cognitive factors mediated the intervention's effect on SRH or FRH. Hence, H2 to H4 were not supported.

As to Educ+InfrRem and Educ+PubRem+InfrRem compared to Educ, again results partly differed for SRH and FRH. In line with H5 and H6, descriptive and injunctive norms were enhanced by Educ+InfrRem and Educ+PubRem+InfrRem and significantly mediated the interventions' effects on SRH and FRH. Stool-related commitment strength was neither affected by Educ+InfrRem nor Educ+PubRem+InfrRem; food-related commitment strength, however, mediated the interventions' effects on FRH. Therewith, H7 was only partly supported. In line with H8, forgetting was mitigated by Educ+InfrRem and Educ+PubRem+InfrRem and significantly mediated the interventions' effects on SRH and FRH. Motivational self-efficacy was enhanced by Educ+InfrRem and Educ+PubRem+InfrRem, and significantly mediated the interventions' effects on SRH and FRH with one exception: the indirect effect of Educ+InfrRem on SRH was not significant, supporting H9 only partly. Volitional self-efficacy was only significantly enhanced by Educ+PubRem+InfrRem but not by Educ+InfrRem. It significantly mediated the previous intervention's effects on SRH and FRH. H10 was thus only partly supported. In line with H11, impediments were mitigated by Educ+InfrRem and Educ+PubRem+InfrRem, and mediated the interventions' effects on SRH and FRH.

Table 1 Means, standard deviations and Pearson correlations for changes in stool-related handwashing (below diagonal), in food-related handwashing (above diagonal) and in social-cognitive factors

Variables[a]	HW	DN	IN	Forget	CS	MSE	VSE	Imped	*M*	*SD*
HW		0.53***	0.27***	−0.4***	0.32***	0.18***	0.24***	−0.27***	−0.04	0.33
DN	0.49***		0.36***	−0.29***	0.35***	0.13**	0.31***	−0.28***	0.01	0.29
IN	0.24***	0.29***		−0.08	0.31***	0.11*	0.41***	−0.02	0.13	0.33
Forget	−0.36***	−0.29***	−0.05		−0.16***	−0.09*	−0.13**	0.54***	0.42	2.22
CS	0.34***	0.28***	0.25***	−0.12**		0.32***	0.24***	−0.2***	0.06	0.25
MSE	0.16**	0.16***	0.2***	−0.1*	0.24		0.1*	−0.03	0.07	0.30
VSE	0.24***	0.32***	0.44***	−0.14**	0.19***	0.12**		−0.1*	0.25	0.32
Imped	−0.26***	−0.22***	−0.01	0.54***	−0.12**	−0.05	−0.09*		0.66	2.17
M	−0.01	0.04	0.11	0.40	0.12	0.10	0.25	0.64		
SD	0.33	0.29	0.35	2.21	0.25	0.27	0.32	2.16		

$N = 404$. *HW* handwashing, *DN* descriptive norm, *IN* injunctive norm, *Forg* forgetting, *CS* commitment strength, *MSE* motivational self-efficacy, *VSE* volitional self-efficacy, *Imped* impediments

[a] Variables reflect changes in behaviour and in social-cognitive factors from baseline to follow-up

* $p \leq .05$; ** $p \leq .01$; *** $p \leq .001$

Table 2 Simple mediation results regarding changes in stool-related handwashing: comparing intervention groups to the control group

Social-cognitive factors	b path	Intervention groups[a]											
		Educ+PubRem				Educ+InfrRem				Educ+PubRem+InfrRem			
		a path	Indirect effects (axb path; 90 % CI)			a path	Indirect effects (axb path; 90 % CI)			a path	Indirect effects (axb path; 90 % CI)		
			LL	*B*	UL		LL	*B*	UL		LL	*B*	UL
Descriptive norm	0.46***	0.62**	**0.11**	**0.29**	**0.47**	0.79***	**0.19**	**0.36**	**0.55**	1.05***	**0.30**	**0.49**	**0.69**
Injunctive norm	0.21***	0.30†	−0.01	0.06	0.15	0.61**	**0.05**	**0.13**	**0.22**	0.60**	**0.04**	**0.13**	**0.23**
Commitment strength	0.32***	−0.14	−0.16	−0.04	0.06	0.22	−0.04	0.07	0.19	0.30†	−0.02	0.09	0.22
Forgetting	−0.32***	−0.12	−0.06	0.04	0.14	−0.65**	**0.11**	**0.21**	**0.33**	−0.66**	**0.11**	**0.21**	**0.34**
Motivational self-eff.	0.13**	0.18	−0.04	0.02	0.09	0.42*	−0.01	0.05	0.13	0.54**	**0.00**	**0.07**	**0.15**
Volitional self-eff.	0.21***	−0.06	−0.10	−0.01	0.09	0.31†	−0.02	0.06	0.17	0.44*	**0.00**	**0.09**	**0.21**
Impediments	−0.22***	0.06	−0.09	−0.01	0.07	−0.60**	**0.05**	**0.13**	**0.24**	−0.49*	**0.02**	**0.11**	**0.21**

$N = 403$. *Educ* education, *PubRem* public commitment with reminder, *InfrRem* infrastructure-promotion with reminder, *CI* confidence interval, *LL* lower limit, *UL* upper limit. b path = effects of the mediators (i.e. changes in social-cognitive factors) on changes in behaviour. a path = effects of the interventions on the mediators (i.e. changes in social-cognitive factors). Indirect effects were calculated by bootstrapping (bold: significant effects). Displayed are partly standardized coefficients

[a] Intervention groups were coded with dummy-coding using education only as the reference group

† $p \leq .10$; * $p \leq .05$; ** $p \leq .01$; *** $p \leq .001$. One tailed significance levels are presented

Table 3 Simple mediation results regarding changes in food-related handwashing: comparing intervention groups to the control group

Social-cognitive factors	b path	Intervention groups[a]											
		Educ+PubRem				Educ+InfrRem				Educ+PubRem+InfrRem			
		a path	Indirect effects (axb path; 90 % CI)			a path	Indirect effects (axb path; 90 % CI)			a path	Indirect effects (axb path; 90 % CI)		
			LL	*B*	UL		LL	*B*	UL		LL	*B*	UL
Descriptive norm	0.48***	0.40*	−0.02	0.20	0.42	0.77***	**0.15**	**0.37**	**0.61**	0.87***	**0.20**	**0.42**	**0.66**
Injunctive norm	0.23***	0.22	−0.03	0.05	0.13	0.56**	**0.04**	**0.13**	**0.22**	0.65**	**0.06**	**0.14**	**0.25**
Commitment strength	0.29***	0.20	−0.06	0.06	0.18	0.57**	**0.04**	**0.16**	**0.30**	0.53**	**0.03**	**0.15**	**0.29**
Forgetting	−0.35***	−0.12	−0.07	0.04	0.16	−0.65**	**0.12**	**0.22**	**0.35**	−0.66**	**0.11**	**0.23**	**0.36**
Motivational self-eff.	0.14**	0.11	−0.03	0.01	0.07	0.37*	**0.00**	**0.05**	**0.13**	0.47*	**0.01**	**0.07**	**0.15**
Volitional self-eff.	0.20***	−0.06	−0.10	−0.01	0.07	0.31†	−0.02	0.06	0.15	0.44*	**0.00**	**0.09**	**0.19**
Impediments	−0.20***	0.06	−0.09	−0.01	0.06	−0.60**	**0.04**	**0.12**	**0.23**	−0.49*	**0.02**	**0.10**	**0.20**

$N = 407$. *Educ* education, *PubRem* public commitment with reminder, *InfrRem* infrastructure-promotion with reminder, *CI* confidence interval, *LL* lower limit, *UL* upper limit. b path = effects of the mediators (i.e. changes in social-cognitive factors) on changes in behaviour. a path = effects of the interventions on the mediators (i.e. changes in social-cognitive factors). Indirect effects were calculated by bootstrapping (bold: significant effects). Displayed are partly standardized coefficients

[a] Intervention groups were coded with dummy-coding using education only as the reference group

† $p \leq .10$; * $p \leq .05$; ** $p \leq .01$; *** $p \leq .001$. One tailed significance levels are presented

Results from multiple mediation analysis that were inspected to assess the combined importance of the assumed mediators are summarized in Fig. 2. The detailed model parameters are presented in Tables 4 and 5. First, a look at the total, direct and total indirect effects revealed that the social-cognitive factors mediated a large part of the total intervention effects while only one of the direct effects was significant (see Tables 4 and 5). This indicates that compared to Educ in the Educ-plus arms behaviour changed more positively because specific social-cognitive factors were favourably changed. To be more specific, in the multiple mediator models, descriptive norm, commitment strength and forgetting significantly mediated the interventions' effects. However, neither injunctive norm, impediments nor self-efficacy did.

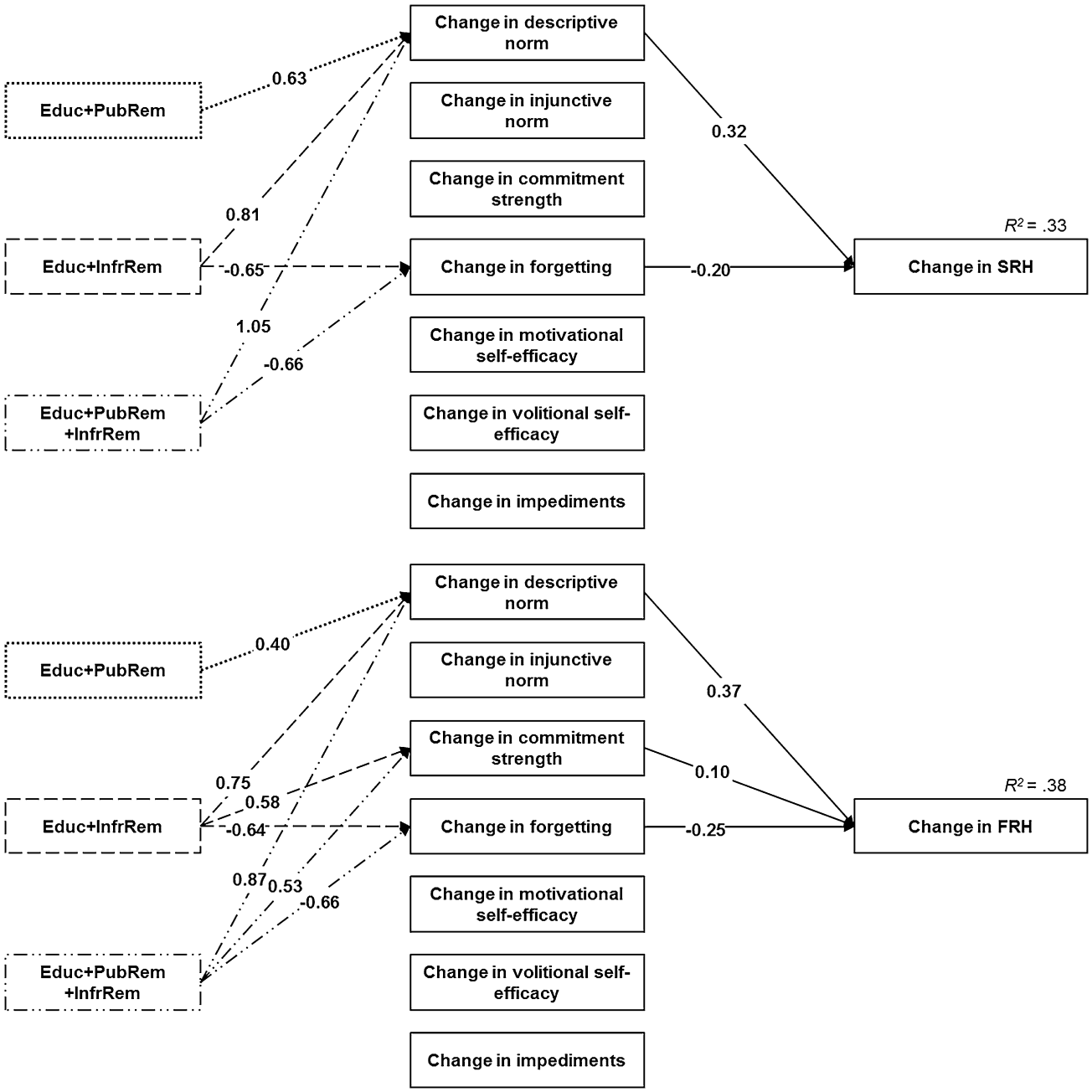

Fig. 2 Multiple mediation results regarding changes in stool-related handwashing (SRH) and food-related handwashing (FRH): comparing intervention groups to the control group. $N = 404$. *Educ* education, *PubRem* public commitment with reminder, *InfrRem* infrastructure-promotion with reminder. *Dotted lines* represent relations between Educ+PubRem and mediators. *Dashed lines* represent relations between Educ+InfrRem and mediators. *Dashed-dotted lines* represent relations between Educ+PubRem+InfrRem and mediators. *Solid lines* represent relations between mediators and handwashing. Only significant relations that result in significant indirect effects are displayed. Partly standardized coefficients are reported

Discussion

This article tested the change processes of two handwashing interventions, a public commitment intervention with reminder and an infrastructure[6] promotion intervention with reminder, in comparison to an education-only intervention in a nonrandomised controlled trial. Based on the RANAS approach (Mosler, 2012), the two interventions were developed not only theory-based but also population-tailored; that is they were matched to the critical social-cognitive factors of handwashing in the target population.

[6] Handwashing stations.

Table 4 Multiple mediation results regarding changes in stool-related handwashing: comparing intervention groups to the control group

Social-cognitive factors	b path	Intervention groups											
		Educ+PubRem				Educ+InfrRem				Educ+PubRem+InfrRem			
		a path	Indirect effects (axb path; 90 % CI)			a path	Indirect effects (axb path; 90 % CI)			a path	Indirect effects (axb path; 90 % CI)		
			LL	*B*	UL		LL	*B*	UL		LL	*B*	UL
Descriptive norm	0.32***	0.63**	**0.08**	**0.20**	**0.35**	0.81***	**0.14**	**0.26**	**0.42**	1.05***	**0.21**	**0.34**	**0.51**
Injunctive norm	0.07†	0.29†	−0.00	0.02	0.08	0.61**	−0.00	0.04	0.12	0.60**	−0.00	0.04	0.12
Commitment strength	0.19***	−0.14	−0.10	−0.03	0.03	0.24	−0.01	0.04	0.13	0.30†	−0.00	0.06	0.15
Forgetting	−0.20***	−0.14	−0.03	0.03	0.10	−0.65**	**0.06**	**0.13**	**0.23**	−0.66**	**0.06**	**0.13**	**0.24**
Motivational self-eff.	0.01	0.18	−0.01	0.00	0.04	0.44*	−0.03	0.00	0.05	0.54**	−0.03	0.00	0.06
Volitional self-eff.	0.03	−0.05	−0.04	−0.00	0.01	0.33†	−0.01	0.01	0.07	0.44*	−0.01	0.01	0.08
Impediments	−0.04	0.05	−0.04	−0.00	0.01	−0.61**	−0.01	0.03	0.10	−0.49*	−0.01	0.02	0.09
Total indirect effects			**0.03**	**0.22**	**0.43**		**0.33**	**0.52**	**0.74**		**0.41**	**0.61**	**0.85**
Direct effects				0.06				0.09				0.20	
Total effects				0.28†				0.62**				0.82***	

$N = 404$. $R^2 = .33$. *Educ* education, *PubRem* public commitment with reminder, *InfrRem* infrastructure-promotion with reminder, *CI* confidence interval, *LL* lower limit, *UL* upper limit. b path = effects of the mediators (i.e. changes in social-cognitive factors) on changes in behaviour. a path = effects of the interventions on the mediators (i.e. changes in social-cognitive factors). Indirect effects were calculated by bootstrapping (bold: significant effects). Displayed are partly standardized coefficients

[a] Intervention groups were coded with dummy-coding using education only as the reference group

† $p \leq .10$; * $p \leq .05$; ** $p \leq .01$; *** $p \leq .001$. One tailed significance levels are presented

Table 5 Multiple mediation results regarding changes in food-related handwashing: comparing intervention groups to the control group

Social-cognitive factors	b path	Intervention groups[a]											
		Educ+PubRem				Educ+InfrRem				Educ+PubRem+InfrRem			
		a path	Indirect effects (axb path; 90 % CI)			a path	Indirect effects (axb path; 90 % CI)			a path	Indirect effects (axb path; 90 % CI)		
			LL	*B*	UL		LL	*B*	UL		LL	*B*	UL
Descriptive norm	0.37***	0.40*	−0.01	0.15	0.33	0.75***	**0.11**	**0.28**	**0.47**	0.87***	**0.15**	**0.32**	**0.52**
Injunctive norm	0.05	0.22	−0.00	0.01	0.06	0.56**	−0.01	0.03	0.10	0.65**	−0.01	0.03	0.11
Commitment strength	0.10*	0.20	−0.01	0.02	0.08	0.58**	**0.01**	**0.06**	**0.14**	0.53**	**0.01**	**0.05**	**0.13**
Forgetting	−0.25***	−0.12	−0.04	0.03	0.12	−0.64**	**0.08**	**0.16**	**0.26**	−0.66**	**0.08**	**0.16**	**0.28**
Motivational self-eff.	0.05	0.11	−0.01	0.00	0.05	0.38*	−0.00	0.02	0.08	0.47*	−0.00	0.02	0.09
Volitional self-eff.	0.02	−0.06	−0.03	−0.00	0.01	0.31†	−0.01	0.01	0.05	0.44*	−0.01	0.01	0.06
Impediments	0.01	0.05	−0.01	0.00	0.02	−0.59**	−0.06	−0.01	0.04	−0.49*	−0.06	−0.01	0.03
Total indirect effects			−0.02	0.21	0.43		**0.29**	**0.54**	**0.77**		**0.36**	**0.60**	**0.84**
Direct effects				0.03				0.10				0.36*	
Total effects				0.25				0.65**				0.97***	

$N = 404$. $R^2 = .38$. *Educ* education, *PubRem* public commitment with reminder, *InfrRem* infrastructure-promotion with reminder, *CI* confidence interval, *LL* lower limit, *UL* upper limit. b path = effects of the mediators (i.e. changes in social-cognitive factors) on changes in behaviour. a path = effects of the interventions on the mediators (i.e. changes in social-cognitive factors). Indirect effects were calculated by bootstrapping (bold: significant effects). Displayed are partly standardized coefficients

[a] Intervention groups were coded with dummy-coding using education only as the reference group

† $p \leq .10$; * $p \leq .05$; ** $p \leq .01$; *** $p \leq .001$. One tailed significance levels are presented

Infrastructure-promotion with reminder and education, alone and in combination with public commitment with reminder, largely predicted changes in social-cognitive factors as expected, and their effects on handwashing were mediated by these. Motivational self-efficacy and social norms were enhanced while impediments and forgetting were decreased. This parallels qualitative research showing that having a handwashing station facilitates behaviour performance (Biran, 2011; Curtis et al., 2009)—which might allow mastery experience and thus increase self-ef-

ficacy—strengthens social norms (Curtis et al., 2009; Devine et al., 2012), makes water and soap easily accessible, and serves as a reminder (Devine & Koita, 2010; Scott et al., 2007). Volitional self-efficacy, however, was only affected by infrastructure-promotion with reminder in combination with public commitment. While differences between the clusters might be responsible for this finding, it is also possible that the public commitment bolstered the infrastructure-promotion's effect on volitional self-efficacy, i.e. served as a moderator. Further, only food-related commitment strength but not stool-related commitment strength was affected by the interventions. This result emphasizes the relevance of considering stool- and food-related handwashing separately when planning and evaluating interventions (Contzen & Mosler, 2012).

In accordance with our expectations, public commitment with reminder and education enhanced the descriptive norm and mediated the Educ-plus combination's effect on changes in stool-related handwashing. Contrasting previous findings (Inauen et al., 2013), however, public commitment with reminder did not increase the injunctive norm and commitment strength. One reason for this finding may lie in the differences of the applied interventions. Whereas Inauen et al. (2013) asked participants to read their implementation intentions to the group, simple pledging was applied in the present research project. Furthermore, the expected influence of reminders (commitment sign and certificate) on forgetting was not found here. The reminding function of the commitment sign, a headscarf, might have failed because the participants seldom wore it, perhaps because they were not accustomed to it. Some have argued that reminders only unfold their effects if they are interpreted as requests (Inauen et al., 2013; Tobias, 2009), which may explain why, in general, the evidence on reminders' effectiveness in improving prospective memory is mixed (Guynn et al., 1998). Intervention developers should thus carefully ensure that the commitment signs are made public, and that they are interpreted as requests. Thereby, commitment and forgetting would be enhanced, and the effect of public commitment should be maximized. Particularly promising would be the use of fixed, permanently worn, or commonly used signs. Future studies should compare the effectiveness of different commitment signs and their processes of change.

In the multiple mediation models only changes in descriptive norm, commitment and forgetting but not changes in self-efficacy and impediments mediated the interventions' effects on change in handwashing. It is credible that the former variables are more behaviour-proximal and mediated not only the interventions effects but also the influence of the latter, potentially more behaviour-distal variables.

Strengths, limitations, and perspectives

To our knowledge, this is the first study to test the underlying mechanisms of handwashing interventions. Further, it is the first application of a public commitment intervention to promote handwashing and the first quantitative test of a handwashing-station-promotion to increase domestic handwashing.

The findings in this study are also subject to some shortcomings. First, intervention allocation was not randomised. A randomised controlled trial (i.e. allocation of interventions to households) was not feasible because the interventions were public (public commitment and handwashing stations constructed at publicly visible places) so that information contamination would have been risked. Instead, interventions had to be allocated to clusters. As the research project was limited to only four kebeles, it was not feasible to conduct a cluster-randomised controlled trial. In nonrandomised trials differences between clusters (i.e. non-comparability of intervention groups at baseline) may blur intervention effects. To enhance the studies internal validity, a replication applying a cluster-randomised controlled trial would be preferable.

Due to untimely termination of the baseline data collection, the control group sample was small. This may have decreased its power to detect significant results.

Further, the limited number of project kebeles qualifies the generalizability of the present findings to other kebeles in the Borena zone or to other regions in Ethiopia.

Due to feasibility issues, handwashing in this study was assessed by self-reports. These tend to be biased due to socially desirable answering tendencies or memory effects so that it is preferable to observe the behaviour instead (Biran et al., 2008; Halder et al., 2010). Nevertheless, the present results are highly relevant, because self-reported handwashing is associated with child diarrhoea, child diarrhoea mortality and cholera infection (Hutin et al., 2003; Luby, et al., 2011b; Water Sanitation and Hygiene Research Group, 2012). Further, all participants, including those in the control arm, received an intervention and should, thus, have been equally inclined to answer in a socially desirable way. If self-reported handwashing was solely contingent on social desirability, a behaviour *increase* should have been reported in all arms. However, there were increases, decreases, and stability in self-reported handwashing. Still, the absolute handwashing rates in this project should be interpreted with caution, and future studies should aim at replicating the results by means of observational data.

Finally, anecdotal evidence suggests that the purpose of the public commitment sign (i.e., the scarf) was misinterpreted (i.e. rather the reminding function was perceived

instead of the expression of commitment). This may have undermined the public commitment intervention's effectiveness (see Contzen et al., 2015).

Conclusions

This study revealed that theory-based population-tailored interventions were more successful in changing handwashing than a standard education intervention, because they successfully changed the critical social-cognitive factors in the target population. Moreover, the study demonstrated not only why the theory-based population-tailored interventions performed well, but also how they might be optimized. Altogether, the present study emphasizes the importance of investigating interventions' underlying change processes.

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Compliance with ethical standards

Conflict of interest Nadja Contzen and Jennifer Inauen declare that they have no conflict of interest.

Human and Animal Rights and Informed Consent The study was in strict accordance with the ethical principles of the American Psychological Association (APA) and the 1964 Declaration of Helsinki and its later amendments. It received ethical approval from the Ethiopian National Research Ethics Review committee and the Faculty of Arts of the University of Zurich. Informed consent was obtained from all individual participants included in the study prior to interviews and interventions.

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