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Make it a habit: how habit strength, goal importance and self-control predict hand washing behaviour over time during the COVID-19 pandemic

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ABSTRACT

Objective: Hand washing has been at the core of recommendations and guidelines that aim to curb infectious diseases in general, and COVID-19 in particular. As hand washing comes down to an individual's behaviour, we aimed to study how individual psychological variables influence hand washing over time during the COVID-19 pandemic.

Design: Over the course of 20 weeks, participants answered questions about their hand washing behaviour, goal importance, habit strength and self-control. Participants from an experimental and a control condition completed a baseline and final measurement, and the experimental condition was invited to bi-weekly measurements through reminders.

Main outcome measure: Hand washing behaviour over the past 14 days was assessed by self-report at baseline and final measurement, and additionally repeatedly over the course of 20 weeks in the experimental condition.

Results: Hand washing behaviour decreased over time, but this decrease was buffered by habit strength and goal importance. The decrease was smaller in the experimental condition that received reminders every 2 weeks.

Conclusion: Sending personal reminders on hand washing behaviour contributes to hand washing behaviour. Moreover, taking habit strength and goal importance, and to a lesser extent self-control into account is important when designing interventions to promote hand washing behaviour.

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KEYWORDS
Hand hygiene; hand washing; habit; goal importance; self-control

Introduction

The COVID-19 pandemic has put the spotlight on behaviour and behaviour change, ranging from social distancing to getting tested and vaccinated, and a wide range of specific behaviours in between. One health behaviour in particular plays a pivotal role in (curbing) the pandemic; hand hygiene behaviour. COVID-19 can spread through contact transmission, and hands play a crucial role; by touching contaminated surfaces,

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other people, and one's own face, the virus can quickly spread (World Health Organization, WHO, 2021). Hand hygiene has therefore been at the core of most recommendations and guidelines that aim to flatten the curve and curb the pandemic; the World Health Organization has called upon policy makers to promote hand hygiene behaviour, and in many countries, refraining from shaking hands and proper hand washing guidelines have been in place for the duration of the pandemic (WHO, 2021). However, calling upon policy makers to promote hand hygiene behaviour and telling people to wash their hands frequently, may not be sufficient to significantly increase hand washing behaviour. As hand washing comes down to an individual's behaviour, individual factors such as self-regulation and habit strength may play an important role, and as such, we aimed to study how these variables interact with hand washing behaviour over time during the COVID-19 pandemic.

In the period preceding the present COVID-19 pandemic, infectious diseases have been a major public health concern for many decades, posing a significant burden on society in terms of individual health, health care and health care costs (Murray et al., 2004). For example, in the Netherlands infectious disease caused by food-related pathogens cause a disease burden of 11,000 disability-adjusted life years, and societal costs of infectious diseases run op to €423 million annually (Lagerweij et al., 2019). Hand washing has always been an area of attention; improving hygiene behaviour has been known to reduce the rate of gastrointestinal infectious disease by 31%, and respiratory illness by 21–24% (Aiello et al., 2008; Rabie & Curtis, 2006). Unfortunately, proper hand washing behaviour is scarce across different contexts. For example, hand washing compliance is low in day-care centres (van Beeck et al., 2016; Zomer et al., 2013), following bathroom use (Freeman et al., 2014), in health care facilities (Boyce, 1999) and when preparing food (Green et al., 2006).

The lack of proper hand washing, and the often limited effectiveness of hand washing interventions (Gawande, 2004; Grant & Hofmann, 2011; Whitby et al., 2007) may be due to a common misunderstanding about human behaviour; namely that once people have the necessary information (about the importance of their behaviour, and how to perform it), they will act accordingly, in a rational, reflected way. Interventions based on this assumption often rely on information and education approaches. However, research has demonstrated that knowledge is often insufficient to cause behaviour change. In fact, automatic processes that do not require deliberation govern most of our behaviour, rather than intentions that only predict a minority of behaviours (Hofmann et al., 2008; Sheeran, 2002). Dual-systems approaches to behaviour leave room for both, and potentially on a continuum; intentions and deliberate behaviour are part of the human experience, but are often overruled (due to strong context-behaviour links that trigger habits, fatigue, or 'hot states') by automatic behaviour (Melnikoff & Bargh, 2018; Strack & Deutsch, 2004; Wood & Rünger, 2016). As such, by providing people with information on hand washing, we may influence their intentions, but not necessarily also their actual behaviour.

There are several potentially important contributors to hand washing behaviour that can be drawn from the field of behaviour change, one of them being goal importance. A goal can be defined as a desired outcome that is discrepant with the current situation (Carver & Scheier, 1998). To what extent people find the goal of adhering to hand washing guidelines important would presumably play a role in

whether or not they perform proper hand washing, as goals stimulate motivation and action (Latham & Locke, 1991). Goal importance, for example signified by goals being in line with one's personal or intrinsic values and interests, also called 'self-concordant' goals, amplifies the potential for action in the shape of goal-congruent behaviour; people act more on goals that are important to them (Deci & Ryan, 2012; Sheldon & Elliot, 1999; Sheldon & Houser-Marko, 2001).

A second relevant construct to consider is self-control. Self-control is a crucial factor when it comes to resolving dilemmas between (important) long-term goals and short-term goals (de Ridder et al., 2018; Gillebaart & de Ridder, 2015; Myrseth & Fishbach, 2009), is also important in the initiation of behaviour (de Ridder & Gillebaart, 2017; Fujita, 2011; Gillebaart, 2018), and develops over time with repeated behaviour (de Ridder et al., 2020; Gillebaart et al., 2020). Hand washing can be considered to be a self-control dilemma; its benefits are relatively abstract to most (although admittedly more concrete during a pandemic), and in the short-term it is more of a hassle than anything else. Zooming in on the current circumstances, realizing the importance of hand washing for near future health and wellbeing may prompt the use of self-control resources to initiate and perform the behaviour, despite its lack of immediate rewards.

Finally, habit strength and habit formation may play a role when people initiate and maintain their hand washing behaviour. Habits are defined as specific, automatized behavioural responses that are triggered by cues in the environment (Verplanken & Orbell, 2003). Habits and habit formation in health behaviour have been studied extensively, ranging from how long it takes to form a habit (Lally et al., 2010; van der Weiden et al., 2020), to how habit strength affects goal pursuit (Aarts, 2007; Neal et al., 2013; Wood, 2016; Wood & Neal, 2007) and health behaviours such as exercise (de Bruijn & Rhodes, 2011), smoking (Orbell & Verplanken, 2010) and snacking (Verhoeven et al., 2012). Proper hand washing is a matter of repetition; washing one's hands frequently after having been outside or having touched high-risk surfaces or other people, as opposed to one-time behaviours such as getting vaccinated. For hand washing, habits may therefore be particularly important: performing hand washing automatically, without having to pay effortful attention, is facilitated if handwashing becomes a habit through cue-dependent repetition (Verplanken & Orbell, 2003).

Despite these theoretical notions about the concepts that may drive hand washing behaviour, empirical findings on underlying processes of hand washing behaviour are mixed. Habit strength seems to play an important role (Diefenbacher et al., 2020; Erasmus et al., 2020), but so do intention, attitude, and self-regulatory variables such as perceived control (De Wandel et al., 2010; Erasmus et al., 2020; Jenner et al., 2002). Most studies done in the area of hand washing behaviour focus on health care settings and/or workers (De Wandel et al., 2010; Erasmus et al., 2020; Grant & Hofmann, 2011; Sassenrath et al., 2016) and the majority of them is cross-sectional in nature. This precludes insight into what constitutes hand washing behaviour in the general population, while hand washing in this group is extremely important in times of COVID-19, and afterwards. It also precludes insight into the development of hand washing behaviour over time; one can imagine that increasing compliance to guidelines may need self-regulatory skills or resources, or intention, but that habit formation will start to play a role once the behaviour has been performed more frequently

(Lally et al., 2010). Moreover, the COVID-19 pandemic forms a unique situation during which people are potentially more aware of (the importance of) hand washing, creating an opportunity to investigate hand washing adherence and the role of self-control, goal importance, and habit strength in increasing or maintaining hand washing behaviour.

The current study was carried out in the Netherlands between March and September 2020, a time where the country combatted the first wave in the COVID-19 pandemic by setting strict guidelines for behaviour (wash your hands regularly, do not shake hands, cough or sneeze in your elbow) as well as lockdown measures from 15 March 2020 onwards (working from home, limitations on group size inside and outside of the house, wearing masks to cover nose and mouth, get tested). This meant a drastic lifestyle change for most people, and the adoption of (semi) new behaviours, with a key role for hand washing. In addition to placing severe constraints on people's lives, this situation also formed a special opportunity to study the development of hand washing behaviour over time, to map how different individual variables would be associated with increases and decreases in behavioural compliance in a general population.

In the current study, we included measures of hand washing behaviour, goal importance, self-control, and habit strength with the aim of providing insight into how this behaviour and potential predictors developed longitudinally. As a primary hypothesis, based on theoretical frameworks on behaviour change and previous studies into habit formation, self-control, and hand washing behaviour (e.g. de Ridder & Gillebaart, 2017; Gillebaart et al., 2020; McCarthy et al., 2017), we predicted that goal importance, habit strength, and self-control would all contribute to hand washing behaviour throughout the course of the study, with a particularly pronounced role for habit strength as opposed to self-control due to the repetition-based nature of hand washing. Goal importance was hypothesized to be an important contributor, as (habitual) hand washing behaviour may become part of one's identity (Verplanken & Sui, 2019), which would lead to people continuously endorsing hand washing as an important personal goal. In addition, bi-weekly reminders were included in the study, and a control condition with a simple baseline and post-measurement was included to be able to isolate the effect of reminders. As previous research has demonstrated that simple reminders to engage in a behaviour promotes habit formation and increases experienced self-control over the behaviour (de Ridder et al., 2020; Gillebaart et al., 2020), as a secondary hypothesis, we expected the reminders to serve as an intervention that would promote hand washing behaviour.

Methods

Participants and design

Participants were recruited via an online panel of a Dutch panel agency. Data collection was performed in accordance with the declaration of Helsinki. The study was approved by the institution's Ethics Review Board (filed under #20-222). Members of the panel registered voluntarily and gave explicit consent to be included in the panel and the current study. A nationwide adult sample living across the Netherlands was

approached by the panel agency. A total of 2088 participants took part in the study, including 1024 females, 1060 males, 3 participants with a different type of gender and 1 participant who chose not to disclose their gender. The age of participants ranged from 18 to 91 (M = 52.04, SD = 17.87). Educational level was low (primary school, preparatory vocational education) for 17.4% of the sample, medium (high school, middle vocational training) for 42.7% and high (higher vocational training, university) for 39.8% of the sample.

The study consisted of a quasi-experimental survey design with two conditions; an experimental group ($N = 1103$) and a control group ($N = 985$), invited by the research panel agency to participate in the study. Both groups were randomly selected from the research panel's database. Participants from both conditions completed the baseline and final measurement, and only the experimental group was invited to complete the recurring bi-weekly measurements. The study ran for twenty weeks between March and September 2020 during which the COVID-19 pandemic was ongoing, with bi-weekly measurements, resulting in ten measurements for the experimental condition and two measurements for the control condition.

Procedure

When participants responded to the panel agency's invitation and entered the study, they were provided with information about the study and asked to sign for informed consent. They were invited into one of the two conditions[1] and proceeded to the baseline measurement. All measurements (baseline, bi-weekly and final) had a similar core set of measurements; self-control, hand washing habit strength, goal importance and hand washing behaviour. The baseline measure had an additional set of demographics questions, and the final measurement had an additional set of exit questions on attribution of behaviour. For the experimental group, participants were invited every two weeks to participate in a measurement. This invitation and the bi-weekly measurement served as a reminder on hand washing behaviour. Both conditions were invited for the final measurement at the end of the study. Participants who skipped more than one measurement were no longer invited to participate ($n = 365$).

Measures

Self-control

Self-control was assessed with a selection of four items from the Brief Self-Control Scale (Tangney et al., 2004) that formed a inhibition subscale (Maloney et al., 2012): 'I am good at resisting temptation', 'I have a hard time breaking bad habits', 'I wish I had more self-discipline', and 'People would say that I have iron self-discipline'. All items were scored on a 5-point Likert scale ranging from 1 (Not at all applicable to me) to 5 (Very much applicable to me). This subscale had a modest reliability with a Cronbach's α of .69. To facilitate interpretation, in the multilevel regression analyses, the self-control measure was transformed into a scale ranging from 0 to 100.

Habit strength

Habit strength was measured using the four items from the Self-Report Behavioural Automaticity Index (SRBAI; Gardner et al., 2012), a shortened from of the Self-Report Habit Index (SRHI; Verplanken & Orbell, 2003) extended with two SRHI items that assess how much the behaviour reflects their identity ('Washing my hands is typically me' and 'Washing my hands would require effort not to do'). Participants were instructed that 'washing my hands' referred to washing hands with water and soap, for at least 20 s, after having been out of the house. All items were scored on a 7-point Likert scale ranging from 1 (Strongly disagree) to 7 (Strongly agree). The scale was reliable with a Cronbach's α of .94. To facilitate interpretation, in the multilevel regression analyses, the habit strength measure was transformed into a scale ranging from 0 to 100.

Goal importance

Goal importance was assessed with 1 item: 'How important is it for you to wash your hands (for at least 20 seconds, using water and soap) after you have been out of the house'? Participants answered this question using a slider that ranged from 0 (Not important at all) to 100 (Very important).

Hand washing behaviour

Adherence to hand washing guidelines was assessed with one item.[2] Participants were informed that guidelines from the Dutch National Institute for Health and the Environment prescribe to wash one's hands with water and soap, for at least 20 s, when one has been out of the house. Then, participants were asked: 'To what extent did you adhere to these hand washing guidelines over the past 14 days?', which was answered using a slider ranging from 0 (Not at all) to 100 (Completely).

Demographics

Participants were asked to indicate their age and gender (female/male/other/rather not say) and level of education.

Data analysis

We analysed the data in SPSS 24 with the Linear Mixed Models, using Maximum Likelihood estimation. First, to examine how self-control, habit strength, goal importance, and hand washing behaviour changed over time, we analysed trends over time in the experimental condition. We carried out a growth curve modelling for self-control, habit strength, goal importance and hand washing behaviour, in which a random intercept, and fixed effects of a linear and a quadratic time trend were estimated. The linear trend was operationalized as the median centred measurement wave (ranging from −4 to +5), and the quadratic trend as the squared linear trend (ranging from 0 to 25). In addition, the random slopes of the linear and quadratic trend were tested to allow for individual differences in the growth curve. In these analyses,

participants with two or more measurements in the experimental condition were included, resulting in 995 participants with 8065 measurements.

Second, the hypothesis that self-control, habit strength, and goal importance would predict hand washing behaviour over time was tested by adding the participants' average self-control, habit strength and goal importance as main effects, and the interactions with the linear and quadratic trend in hand washing behaviour to the regression. In addition, we examined longitudinal relationships between the variables with the contribution of lagged self-control, habit strength and goal importance to the regression of hand washing behaviour, controlled for hand washing behaviour on the previous measurement. Third, we investigated reversed effects of behaviour on these predictor variables. Fourth, to test the hypothesis that reminders would boost hand washing behaviour, differential changes in the experimental and control condition between the baseline and the final measurement were compared using regression analysis. Fifth and finally, we looked at how participants attributed their hand washing behaviour over time to their habit strength and self-control.

Results

Descriptive statistics

Table 1 shows the descriptive statistics for both the experimental and control condition at baseline. We first examined whether there were differences between conditions at baseline. There were no significant differences between both conditions at baseline, except for age, which was higher in the control condition than in the experimental condition (t (2086) = 4.58, $p < .001$).

Of the 2088 participants, 1377 filled out the final measurement (response rate 65.9%), including 642 (58.2%) participants in the experimental condition and 735 (74.6%) participants in the control condition. This shows there was substantially more attrition in the experimental condition ($p < .001$). There was evidence of overall selective attrition with regard to the variables at baseline. Older participants ($p < .001$), and participants with higher self-control ($p < .001$) were more likely to complete the study than younger participants and participants with lower self-control. Younger participants were especially likely to drop out of the control condition ($p < .001$). There as a marginally significant difference in goal importance ($p = .06$), with drop-out participants having a slightly lower goal importance than participants who completed

Table 1. Descriptive statistics at baseline.

	Control condition ($N = 985$)		Experimental condition ($N = 1103$)		Total ($N = 2088$)	
	M	SD	M	SD	M	SD
Self-control capacity	59.06	18.46	57.72	18.88	58.35	18.69
Habit strength	64.16	24.60	65.26	23.77	64.74	24.16
Goal importance	78.76	25.29	80.07	23.82	79.45	24.53
Hand washing	79.78	24.47	80.50	23.44	80.16	23.93
Age	53.93*	17.21	50.36*	18.27	52.04	17.87
Sex (% female)	50.5		47.9		49.1	

*Age differs between the control and experimental conditions, $p < .001$.

Table 2. Correlations at baseline for both the experimental condition (below the diagonal, $N = 1103$) and the control condition (above the diagonal, $N = 985$).

	Self-control	Habit strength	Goal Importance	Hand washing
Self-control	1.00	0.26	0.20	0.24
Habit strength	0.24	1.00	0.58	0.62
Goal importance	0.19	0.52	1.00	0.81
Hand washing	0.18	0.52	0.79	1.00

the study. There were no other significant differences ($p > .10$) between participants who remained in the study and those who dropped out. Table 2 shows the correlations at baseline between self-control, habit strength, goal importance, and hand washing behaviour for both conditions.

Trends over time in self-control, habit strength, goal importance and hand washing behaviour

In total, there were 8065 trials for 995 participants in the experimental group consisting of the ten measurement waves in the experimental condition. Means for all variables were inspected per wave to corroborate the analytic strategy focusing on linear and quadratic trends. First, using a growth curve modelling technique, linear and quadratic trends in goal importance, self-control, habit strength, and hand washing behaviour were analysed for the experimental condition. Hand washing behaviour decreased over time (linear trend, $b = -.36$, $p < .001$), especially during the first waves (quadratic trend, $b = .08$, $p < .001$). Random effects of both the linear trend (Wald $Z = 14.07$, $p < .001$) and the quadratic trend (Wald $Z = 4.73$, $p < .001$) were significant, showing that participants differed in how their hand washing behaviour changed over time. Self-control capacity remained the same over time, neither the linear trend ($b = .06$, *ns*) nor the quadratic trend ($b = -.01$, *ns*) were significant. Goal importance reduced slightly over the course of the ten measurement waves (linear trend, $b = -.25$, $p < .001$), especially during the first few waves (quadratic trend, $b = .07$, $p < .001$). Random effects of both the linear trend (Wald $Z = 13.01$, $p < .001$) and the quadratic trend (Wald $Z = 5.54$, $p < .001$) were significant for goal importance. Habit strength for hand washing increased linearly over time ($b = .33$, $p < .001$), with a significant random effect of the linear trend (Wald $Z = 13.89$, $p < .001$). Cubic trends did not add significantly to any of the tested models.

The influence of self-control, habit strength and goal importance on hand washing behaviour over time

To test the hypothesis that goal importance, self-control, and habit strength would contribute to hand washing behaviour, multilevel regression analyses were conducted with the participant's average values for the different predictors and testing interactions with the linear and quadratic trend. The results are shown in Table 3.

A model with all three predictors included simultaneously shows that goal importance and habit strength were significant predictors of hand washing behaviour, but

Table 3. Trends in hand washing behaviour and the role of self-control, habit strength and goal importance in the experimental condition ($N = 994$).

Predictors	Model 1	Model 2	Model 3	Model 4
Intercept	79.71***	78.89***	79.02***	79.02***
Linear trend		−0.36***	−0.34***	−0.33***
Quadratic trend		0.08***	0.08	0.08***
Average self-control			0.02	0.02
Average habit strength			0.08***	0.08***
Average goal importance			0.89***	0.92***
Linear trend × self-control				0.01
Linear trend × habit strength				0.01*
Linear trend × goal importance				0.02***
Quadratic trend × self-control				−0.00
Quadratic trend × habit strength				−0.00
Quadratic trend × goal importance				−0.00***
Fit (−2 log L)	64,937.23***	64,108.91***	61,845.05***	61,710.18***
Δ fit		828.32***	2,263.86***	134.87***
df		4	3	6

Notes: *$p < .05$; **$p < .01$; ***$p < .001$. In Model 2-4 both fixed and random effects of the linear and quadratic trend are estimated.

the contribution of self-control to the regression of hand washing behaviour was not significant. Significant interactions with the linear trend were found for goal importance and habit strength, but not for self-control. This was partially in line with our primary hypothesis. Moreover, the interaction of goal importance with the quadratic trend was significant as well. This resulted in different growth curves for individuals with high (M + 1SD) and low (M − 1SD) goal importance and habit strength. This is shown in Figure 1. For those with higher habit strength, hand washing behaviour remains stable over time, while for those with lower habit strength, hand washing compliance decreases. A similar, but much stronger, pattern was observed for goal importance, with a large main effect of goal importance. Those scoring high on goal importance consistently comply and even increase their hand washing behaviour over time, whereas those scoring low on goal importance, are much less compliant and show a decrease in hand washing behaviour.

In addition to investigating the influence of the *average* values of the predictors, similar analyses were conducted with *lagged* predictors: longitudinal analyses were done to examine to what extent hand washing behaviour could be predicted by hand washing behaviour at the previous wave, and by self-control, habit strength and goal importance at the previous wave. Results are presented in Table 4.

Regression analyses revealed that (lagged) hand washing behaviour at the previous wave contributed substantially to the regression of hand washing behaviour (Model 2). Model 3 showed that self-control, habit strength and goal importance at the previous wave all contributed positively to hand washing behaviour, even after controlling for hand washing behaviour at the previous wave. This was in support of our primary hypothesis. This means that participants were more likely to continue

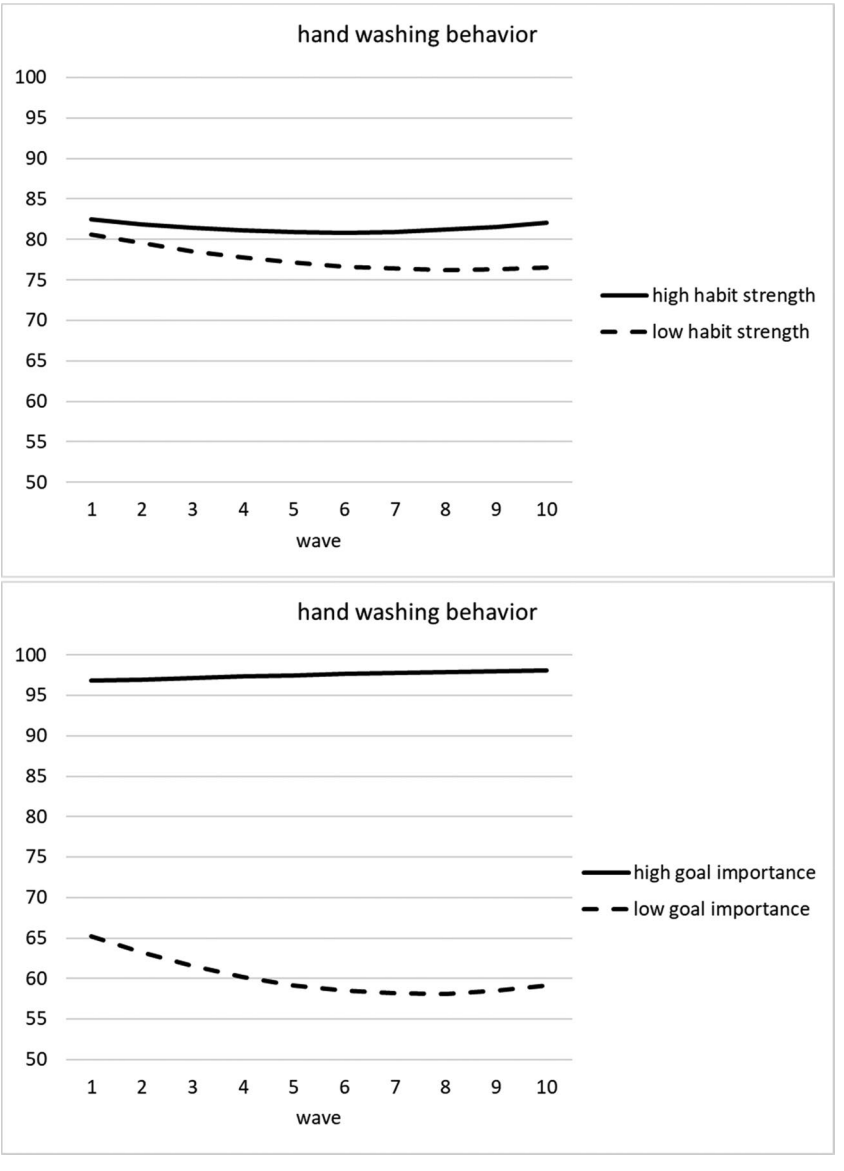

Figure 1. Trend lines for the influence of M + 1SD and M – 1SD goal importance and habit strength on hand washing behaviour.

their hand washing over time when they were higher in self-control, had formed a stronger habit, and regarded a good hand washing a more important goal at the previous measurement. These results confirm those presented above and, in addition, show that although average self-control did not significantly contribute to predicting hand washing behaviour, self-control at a previous measurement was a significant predictor.

Table 4. Longitudinal multilevel regression of hand washing behaviour and lagged predictors in the experimental condition ($N = 994$).

Predictors	Model 1	Model 2	Model 3
Intercept	79.44***	79.45***	79.53***
Lagged hand washing behaviour		0.37***	0.34***
Linear trend		−0.11*	−0.14**
Lagged self-control			0.04**
Lagged habit strength			0.15***
Lagged goal importance			0.20***
Fit (−2 log L)	56,383.88***	55,590.76***	55,181.81***
Δ fit		793.12***	408.95***
df		2	3

Note: *$p < .05$; **$p < .01$; ***$p < .001$.

Table 5. Longitudinal multilevel regression of self-control, habit strength, and goal importance (all scaled from 0 to 100) in the experimental condition ($N = 995$ for self-control and goal importance, $N = 994$ for habit strength).

Predictors	Self-control	Habit strength	Goal importance
Intercept	59.08***	67.56***	79.51***
Lagged self-control	0.18***		
Lagged habit strength		0.36***	
Lagged goal importance			0.14***
Linear trend	0.03	0.24***	0.01
Lagged hand washing behaviour	0.04***	0.15***	0.33***

Note: *$p < .05$; **$p < .01$; ***$p < .001$.

The influence of hand washing behaviour on self-control, habit strength and goal importance

In addition to the predictive value of self-control, habit strength and goal importance for hand washing behaviour, it was exploratively examined to what extent hand washing behaviour at the previous wave contributed to self-control, habit strength and goal importance. Table 5 shows that behavioural compliance contributed positively to the regression of all three variables. This means that self-control, habit strength and goal importance increase (or remain high) over time if participants consistently complied with the hand washing guidelines in the previous period.

The effect of reminders: differences between conditions

To test the secondary hypothesis that the reminders in the experimental condition would increase hand washing behaviour, we analysed differences between conditions. Linear regression analyses were performed with the post-measurement as a dependent variable, and baseline measurement and condition as predictors. Means and standard deviations are presented in Table 6.

In a set of regression analyses, hand washing behaviour and the predictors were included as dependent variables, with the same variable at baseline and condition

Table 6. Means and standard deviations for baseline and post-measurements of self-control, habit strength, goal importance and hand washing compliance for the control and experimental condition.

	Experimental condition ($N = 642$)		Control condition ($N = 735$)	
	Baseline	Post-measurement	Baseline	Post-measurement
	M (SD)	M (SD)	M (SD)	M (SD)
Self-control	3.31 (0.76)	3.41 (0.83)	3.36 (0.74)	3.39 (0.75)
Habit strength	4.91 (1.43)	5.16 (1.60)	4.85 (1.48)	4.94 (1.55)
Goal importance	80.01 (23.82)	79.99 (24.57)	78.76 (25.29)	76.01 (26.33)
Hand washing behaviour	80.50 (23.44)	79.45 (24.53)	79.78 (24.47)	76.56 (25.94)

Table 7. Regression results for the predictive value of baseline value and condition on post-measurement levels of hand washing behaviour, self-control, habit strength and goal importance.

	B	*t*	*p*
Hand washing behaviour			
Hand washing behaviour at baseline	0.64	30.97	<.005**
Condition	0.04	2.17	<.05*
Self-control			
Self-control at baseline	0.70	35.92	<.001***
Condition	0.03	1.40	.16
Habit strength			
Habit strength at baseline	0.70	37.01	<.001***
Condition	0.04	2.33	<.05*
Goal importance			
Goal importance at baseline	0.65	31.90	<.001***
Condition	0.05	2.66	<.005**

Note: *$p < .05$; **$p < .01$; ***$p < .001$.

as predictors. Results are presented in Table 7. Hand washing behaviour decreased slightly more in the control condition than in the experimental condition. Habit strength increased more in the experimental compared to the control condition. Goal importance decreased over time, but only in the control condition.

Attributions of hand washing behaviour

As an exploratory analysis, we assessed how participants attributed their own hand washing behaviour. Participants who indicated to have washed their hands in line with hand washing guidelines over the course of the study were asked to what extent they complied because it became a habit, and to what extent they complied because of self-control. Out of 1377 participants at post-measurement, 1197 indicated to have generally complied with hand washing guidelines over the past few months. On scales ranging from 0 to 100, participants indicated that they complied to hand washing guidelines because it became a habit with an average of 79.81 (SD = 21.14), and because they used self-control with an average of 69.71 (SD = 27.88). Participants in the experimental condition attributed their compliance significantly (both $p < .05$), more to both habit strength ($M = 81.19$, SD = 20.66) and to self-control ($M = 71.72$, SD = 27.39) than those in the control condition (respectively, $M = 78.57$, SD = 21.51, and $M = 67.89$, SD = 28.20).

A minority of 180 participants indicated not to have complied with hand washing guidelines over the course of the study. Of these 180 participants, 65 (36.1%) indicated that they did not believe hand washing was effective, 14 (7.8%) indicated it was no fun, 23 (12.8%) indicated it was too difficult, and 78 participants (43.3%) indicated other reasons for not complying, for example perceiving most outdoor activities as low risk, forgetfulness and skin problems.

Discussion

In this study, participants were followed over the course of 20 weeks and surveyed about their hand washing behaviour and potential predictors of compliance to hand washing guidelines recommended in the COVID-19 pandemic countermeasures. First, several trends over time were observed. A small but significant linear decrease in hand washing behaviour was observed. This could indicate that hand washing behaviour at baseline was overestimated due to the participants taking part in a study on this topic, and/or the decrease could indicate a generally felt decrease in urgency considering COVID-19 countermeasures over time. This is in line with an observed decrease in goal importance as well, that mainly occurred in the first few measurements, levelling off for the remainder of the study. Self-control remained stable, which is in line with the notion of *trait* self-control, considering self-control as a personality trait that is stable over time and contexts (Tangney et al. 2004). As expected, habit strength for hand washing increased over time.

Second, the hypothesis that self-control, habit strength and goal importance would contribute to hand washing behaviour over time was supported by the analyses: The decrease in hand washing behaviour was less pronounced for people with a stronger hand washing habit and a higher goal importance, whose hand washing compliance remained relatively stable. A similar trend was observed for high and low trait self-control, albeit not significant, which was in line with our hypothesis on relative contribution of the different factors. Specifically, when taking lagged self-control into account, people with higher self-control showed more stable hand washing compliance than people with lower self-control. Summarizing, a high level of hand washing habit strength, goal importance, and self-control all buffered against a decrease in hand washing compliance. Interestingly, in a third set of analyses, it was demonstrated that the dynamics between predictors and hand washing behaviour were reciprocal in nature: self-control, habit strength and goal importance could be predicted from hand washing behaviour preceding the measurement. These reversed effects are highly relevant as they show that reciprocal relationships exist in which the actual behaviour and the accompanying psychological factors reinforce each other over time.

Fourth, participants in the experimental condition were invited for surveys every two weeks, and to isolate effects from these reminders, a control condition was included with a baseline and post-measurement only. In line with our secondary hypothesis, reminding people about their hand washing behaviour, habit strength, goal importance and self-control every 2 weeks, indeed made a difference. Habit strength increased more in the experimental condition than in the control condition, and goal importance decreased less in the experimental condition than in the control condition. In general, hand washing behaviour decreased over time, but this decrease was buffered by the

reminders formed by the survey invitations; the decrease was stronger in the control than the experimental condition. Fifth, and finally, people were more likely to attribute their hand washing behaviour to habit strength than to self-control, and attribution values were generally higher in the experimental condition.

Taken together, the results of this longitudinal study support our hypotheses on the relevance including individual psychological factors when predicting hand washing behaviour, as self-control, goal importance, and habit strength were all valuable predictors of behaviour. Moreover, regularly enquiring about these psychological factors and people's hand washing behaviours resulted in higher compliance to hand washing guidelines, alluding to the potential of sending out frequent reminders as an intervention. Moreover, findings from the study are relevant for advancing towards more comprehensive theoretical frameworks on behaviour and behaviour change.

Many hand washing interventions in the past have focused on informing people on the importance of hand washing by providing information and education. Although these types of interventions suffer from limited effectivity (Gawande, 2004; Grant & Hofmann, 2011; Whitby et al., 2007), our results show that they need not be obsolete, as they do speak to the notion of goal importance; by informing people about the importance of hand washing, chances that they adopt this as an important behavioural goal may increase. This goal importance may in turn contribute to hand washing behaviour (Deci & Ryan, 2012; Latham & Locke, 1991; Sheldon & Houser-Marko, 2001; Sheldon & Elliot, 1999), as results from the current study also show.

However, it may be more important to facilitate habit formation, and/or increases in habit strength. Theoretically, habits would play an essential role in hand washing behaviour, as habits rely on repetition, as does proper hand washing behaviour. Moreover, in general, habitual behaviour takes place without effort or attention (Verplanken & Orbell, 2003), meaning that it can take place under circumstances that would otherwise hi-jack effort or attention away from the desired behaviour, such as fatigue, cognitive busyness or distractions (McCarthy et al., 2017; Neal et al., 2013; Wood, 2016). Indeed, habit strength played a key role in our results; hand washing compliance was more stable if a stronger hand washing habit was in place. Interestingly, the study itself contributed to habit strength, as was demonstrated by the increase in habit strength in the experimental condition that had bi-weekly reminders. This implies that intervention efforts can capitalize on the unique contribution of habit strength and in turn behaviour by boosting said habit strength via repeated reminders. It is important to note that in this study, reminders may have partially been effective because of their personal nature; an email was sent directly to participants. More general reminders in public spaces for example, may have a weaker effect due to people not feeling like they are being addressed personally. In addition, future research should focus on predictors of habit formation in hand washing behaviour, which may include the personal nature of reminders, but also the formation of new cue-behaviour associations, type of cues, consistency and attention (see also Lally & Gardner, 2013).

The results also shed further light on the relative contributions of effortful and effortless mechanisms of behaviour change (Aarts 2007; McCarthy et al. 2017; Neal et al. 2013; Wood 2016; Wood & Neal 2007), by comparing how habit strength and self-control play respective roles in hand washing behaviour. Both factors are of importance; hand washing compliance is higher when habit strength is higher, but

also when self-control is higher. It is worth noting however, that the contribution of self-control is relatively small. This is in line with recent developments in the field of self-regulation. Self-regulation in general, and self-control in particular, tended to be viewed as effortful mechanisms guiding behaviour (Baumeister & Heatherton, 1996; Muraven & Baumeister, 2000): by effortfully resisting immediate temptations, people can pursue their long-term goals. Recent developments in this field have shifted this perspective, by proposing that self-regulation need not always be effortful, and in fact, may be fuelled by less effortful strategies instead (de Ridder & Gillebaart, 2017; Gillebaart & de Ridder, 2015; Hennecke & Bürgler, 2020). Automatization, routines, and habits are included as potential 'strategies' to make striving for long-term goals easier and more successful (Adriaanse et al., 2014; Galla & Duckworth, 2015; Gillebaart & Adriaanse, 2017). Congruently, self-control (i.e. controlling one's behaviour) was important in predicting hand washing behaviour, but not as important as the more efficient habit strength. These findings therefore support this contemporary view on self-regulation of behaviour; the key may lie in facilitating a certain 'ease of behaviour', and not in fuelling effortful control of behaviour. It may also be the case that goal importance, self-control and habit strength interact in specific ways when explaining behaviour over time (e.g. Aarts 2007; de Ridder et al. 2020; de Ridder & Gillebaart 2017; Gillebaart et al. 2020; McCarthy et al. 2017; Ouellette et al. 1998; Van der Weiden et al. 2020; Wood 2016; Wood & Neal 2007). For example, there may be certain necessary thresholds of goal importance and self-control that are necessary as long as behaviour is under effortful control. Moreover, habit strength may affect this threshold as it reflects a more effortless guiding of behaviour. In future studies, these dynamics between predictors can be considered further.

Several strengths and limitations are worth noting. One of the strengths of the current study is the inclusion of a broad sample from the Dutch population, with a balanced distribution of gender, age, and education level. Furthermore, the longitudinal nature of the study allows for sophisticated analyses of relative contributors to hand washing behaviour, going beyond cross-sectional associations between variables. Finally, the inclusion of a control condition consisting of a baseline and post-measurement resulted in additional insight into predictors of hand washing behaviour, as it allowed for isolation of the effect of simply reminding people about their behaviour. However, this study also comes with limitations. For example, it relied solely on self-report, which means there may be bias in several ways; people may over-report on their hand washing behaviour because of social desirability, and they may not have the proper insight into their own psychological mechanisms underlying behaviour. Future research may address this by studying similar processes including behavioural observation. Furthermore, although a broad sample was included, several participants dropped out during the 20-week study, and these participants may differ from the rest of the participants in how they responded to prompts and questions used in the study. In future studies, follow-up exit interviews with dropped out participants may provide insight into potential differences between groups of participants. Another limitation entails the retrospective reporting that participants were asked to do, which may also be prone to bias. Future studies may include methodologies such as ecological momentary assessment to get a more direct measurement of behaviour and potential predictors.

Conclusion

Hand hygiene in general, and hand washing in particular, is one of the key behaviours that are stimulated to curb the COVID-19 pandemic (WHO, 2021), but is also of vital importance for public health in general now and in the future (Aiello et al., 2008; Rabie & Curtis, 2006). Our findings suggest strategies to promote sustained hand washing behaviour over time. In general, our pattern of findings suggests that reminding people of hand washing guidelines by asking them about their behaviour and psychological predictors, habit strength, goal importance and self-control all contribute to sustained hand washing behaviour. Specifically, reminders may affect behaviour directly, but may also hold the potential for boosting habit strength, which in turn would allow for effortless and sustainable behavioural compliance. As such, this may be a fruitful avenue for interventions.

Notes

1. Due to an assignment error, the experimental and control condition were not equal in size, with 1103 participants in the experimental condition, and 985 participants in the control condition.
2. Initially, a second item was used to assess hand washing behaviour: 'How often did you wash your hands after having been out of the house yesterday'. However, oftentimes this resulted in missing values because people did not leave the house the day before, causing a suboptimal variable that did not provide the desired information. Therefore, this measure will not be reported on.

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